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Plastic Media Blasting Recycling Equipment Study

ABSTRACT Different systems for recycling plastic media were evaluated for operational performance, losses, efficiency, and metal removal. An optimum recycling system was selected which included a cyclone for gross air/media separation, a vibrating screen to remove extra large and extra small particles, and a self-cleaning magnetic separator for ferrous particle removal.

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Different systems for recycling plastic media were evaluated for operational performance, losses, efficiency, and metal removal. An optimum recycling system was selected which included a cyclone for gross air/media separation, a vibrating screen to remove extra large and extra small particles, and a self-cleaning magnetic separator for ferrous particle removal.

FOREWORD

This work was sponsored by the Naval Facilities Engineering Command and the Naval Civil Engineering Laboratory as part of the program to implement Plastic Media Blasting (PMB) in the Navy. This work is an excellent technical evaluation of the operation of plastic media recycling equipment at two Department of Defense (DOD) facilities in terms of recycling efficiencies and hard particle removal.

This work will be used to improve the selection and operation of plastic media recycling equipment at DOD facilities.

If you have additional need for information or an update on our work in this area, please contact:

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PLASTIC MEDIA BLASTING RECYCLING EQUIPMENT STUDY

EXECUTIVE SUMMARY

Plastic Media Blasting (PMB) is a new technology introduced as a candidate to replace wet chemical paint stripping of airframes and component parts. This report documents the physical testing, observations, and laboratory analyses used to evaluate the effectiveness of plastic media recycling equipment at three PMB sites.

The tests were conducted at a walk-in booth at the Naval Aviation Depot (NAVAVNDEPOT) Pensacola, Florida, and at a walk-in booth and a larger F-4 aircraft blast room at Hill Air Force Base (AFB) in Ogden, Utah. Samples of plastic media and/or dust were taken at key locations in the media recycle stream. These samples were analyzed to determine particle size distribution, specific gravity, silica concentration, and total and leachable metal content. Air flow through the booths and ducting was also measured. The following paragraphs highlight key findings.

Media Degradation

Media degradation was approximately 6 percent of the initial media charge. Degradation rates will vary based on media type, hardness, size, blast pressure, substrate being blasted, coating types, and other factors.

Recycling Efficiency

The NAVAVNDEPOT Pensacola booth recovered approximately 81 percent of the media with each pass through the PMB system (includes media degradation). The cyclone separator is responsible for the majority of media losses. The automatic floor recovery system and the vibrating screen both functioned adequately. Ventilation duct design minimized media intrusion into the ventilation system.

The recycling system at the Hill AFB walk-in booth recovered about 86 percent of the media with each pass through the PMB system (includes media degradation). Actual booth losses, however, are much higher due to media entrained in the ventilation system. Media is inadvertently carried into a ventilation exhaust duct when media accumulations at the nearby recovery pit become to great. The air classifier is responsible for a large portion of media losses. The vibrating screen lost about 1 percent of the media on each pass.

Metal and Silica Contamination in Recycled Media

Media samples collected at the three sites were subjected to specific gravity determinations. In general, it was found that the specific gravity tends to increase as the hard particle contamination in the media increases. Analyses to determine the silica concentration of samples indicate that silica concentration increases as particle size decreases. The chemical analysis employed did not differentiate between sand particles and silica present in pigments, therefore, the data does not represent the concentration of hard sand particles in recycled media. A density based separation (usually a float technique) should be used in future studies to quantify the concentration of harder, denser particles in recycled media.

Samples of recycled media were analyzed for total metals content. New media samples were also tested to determine baseline concentrations. Surprisingly high concentrations of zinc and barium were found in the Polyplus media manufactured by U.S. Technology Corporation (U.S. Tech) used at Hill AFB. High lead levels were present in the unused U.S. Tech Polyextra media used at NAVAVNDEPOT Pensacola. The high initial concentration of these metals are a factor when disposing of media dust and rejected material as hazardous waste, indicating that paint/primer are not the only source of metals contamination.

Baghouse dust samples and samples of rejected media were sieved into size ranges, and analyzed for leachable metals concentration. Chromium and cadmium levels for the dust and media exceed the maximum allowable concentration (MAC) established by the Environmental Protection Agency at each site. The MAC for lead was exceeded at all sites in material smaller than 100 mesh size.

Recylcing System

Blasting rooms equipped with full or partial floor recovery systems are recommended where economically justified by labor savings and increased productivity. Automated media recovery minimizes the possibility of reintroducing settled PMB dust into the work environment. The use of a cyclone separator and an additional air wash (air knife) for initial fine dust removal is recommended. A vibrating screen for subsequent particle size separation is recommended for systems not utilizing the additional air wash. Systems equipped with an air wash may use a stationary oversize particle screen. An automatic, self-cleaning magnetic separator is required to remove ferrous debris from the particle stream. With properly sized equipment, this combination would be capable of removing the majority of contamination while recycling nearly all of the usable media.

Economics

Properly desinged and sized PMB recycling equipment minimizes reusable media losses through the system. Assuming conservative production blasting conditions, (media flow rate, nozzle time, and recovery percentages) savings of approximately $360,000 could be realized by achieving the optimum media recovery percentage.

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Enclosure 1 Plastic Media Blasting Recycling Equipment Test Plan

1.0 INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) has been tasked to determine the effectiveness of Plastic Media Blasting (PMB) recycling equipment. Engineering Management Concepts (EMC) of Camarillo, California has been contracted to assist the NCEL in this task. This report documents the work performed by EMC in support of the NCEL task.

Two walk-in booths and an F-4 aircraft blast room (each manufactured by a different company) were evaluated. Performance studies of the various recycling equipment, including cyclones, screens, and magnetic separators, were accomplished. These studies included an evaluation of associated equipment: dust collectors, room ventilation, and floor pick-up systems. Equipment manufacturers and operators provided information about equipment performance, operating parameters, and blasting procedures.

1.1 Objective

The objective of this task was to evaluate the performance of PMB recycling equipment. This performance evaluation addressed:

- Equipment reliability
- Design parameters
- Ease of operation and maintenance
- The percentage of usable media recycled by the system
- Recycled media dust concentrations
- Rejected media properties

Samples of recycled media and rejected dust were analyzed for size distribution, specific gravity, and specified contaminants. These samples were collected during actual blast operations using methods that did not alter media properties or flow rates.

1.2 Background

Plastic Media Blasting is a new technology introduced as a candidate to replace wet chemical stripping of painted airframes and component parts. The process utilizes small, rough plastic beads that are dispersed at high velocity through a nozzle at a painted surface.

Economic comparisons of PMB versus other paint removal procedures have been based largely on the costs of waste disposal and the amount of media regularly purchased to replace non-recycled material. Effective recycling systems reduce the volume of hazardous waste generated and also reduce new media purchases. Plastic media is currently sold for approximately $2.00 per pound, and even small increases in equipment efficiency can produce substantial cost savings.

1.3 Technical Approach

Three PMB sites, and their associated recycling equipment, were subjected to similar testing approaches. A test plan was prepared to aid in the evaluation of PMB recycling equipment and is included as Enclosure 1. The step-by-step procedures of this plan were employed to collect samples and information used in the equipment evaluation. Data and information regarding equipment performance, reliability, and maintainability were acquired on-site through observation and interviews with personnel.

A general overview of PMB recovery and recycling equipment is discussed in section 2 of this report. Information obtained from PMB equipment manufacturers is included in this section. Media and/or dust samples were collected at key points in the recycling system. Several methods were utilized for obtaining the samples. Data and sample acquisition is discussed in the test plan and in sections 3, 4, and 5 of this document. Section 6 presents analyses of the collected data; section 7 provides cost estimates associated with media losses in the systems studied. Recommendations are summarized in section 8.

1.4 Test Site Descriptions

The three test sites that were subjected to testing and evaluation are described below.

1. Walk-in-booth at Naval Aviation Depot (NAVAVNDEPOT) Pensacola, Florida. This small parts walk-in booth measures approximately 10 feet (ft) wide by 20 ft long and utilizes equipment produced by Zero Manufacturing Company.

2. Walk-in-booth at Hill Air Force Base (AFB), Ogden, Utah. This small parts walk-in booth is approximately 15 ft wide by 30 ft long and employs equipment manufactured by CABER Incorporated.

3. F-4 aircraft booth at Hill AFB, Ogden, Utah. The F-4 aircraft blast booth measuring approximately 45 ft wide by 74 ft long utilizes equipment manufactured by Pauli and Griffen, Incorporated. The booth was designed and installed by Royce Mechanical Systems, Incorporated.

2.0 DESCRIPTION OF GENERAL PMB RECYCLING SYSTEM

Plastic media expended during the blasting operation is collected, cleaned, sized, and returned to the blast vessel for use by a media recovery and recycling system. The system retrieves blasted media from the floor of the enclosure and separates dust, large particles, iron, silica, and other contamination from the reusable media. Methods for media retrieval and cleaning/classification are discussed in the following paragraphs.

2.1 Floor Recovery Systems

Blasted media is collected and conveyed to the recycling equipment by a floor recovery system. Floor recovery systems can be broadly placed into four categories.

- Full floor recovery systems
- Partial floor recovery systems
- Manual recovery systems
- Portable recovery systems

A full floor recovery system automatically removes blasted material from all areas of the floor. The booth floor is constructed of open metal grating. Material falls through the grates and is conveyed by various methods to the recycling system. Operator assistance is not required to convey blasted material to the recycling system. A partial recovery system utilizes a system of grates similar to the full floor system, however, the grates do not cover the entire floor. Grate covered troughs, or pits, are located under areas where the majority of blasted material falls. Material that does not fall through the grating must be swept into the trough or vacuumed directly into the recycling system. After the material falls through the grate it is automatically conveyed to the recycling system. A manual recovery system requires personnel to sweep and vacuum material from the floor directly into the recycling system. There is no form of automatic conveyance to move material from the floor to the recycling system. Manual material recovery is labor intensive. A portable recovery system does not utilize any type of permanent material conveyance system. A large vacuum inlet is used much like a portable recovery pit. The device can be located under the area where most of the blasted material is expected to fall and can be moved depending on the configuration of the item being blasted. Material is then pneumatically conveyed to the recycling system.

Full and partial floor recovery systems use various methods to convey material to the recycling system. Pneumatic and mechanical options are the most common. Pneumatic floor systems typically utilize a system of small hoppers under an open grate floor. Blasted material fills the hoppers and is then conveyed by air into the recycling system. Another type of pneumatic floor uses movable suction arms under the grate floor to vacuum material into the recycling system.

Pneumatic floors are effective in conveying material to the recycling system. Maintenance requirements are generally minimal. Pneumatic floors, however, can experience plugging when the supply air is insufficient or when air flow through the floor hoppers is not equal. Moisture in the system causes the media to agglomerate and plug the pneumatic ducting.

Mechanical floor systems utilize a variety of material conveyance methods. Belt conveyors, screw conveyors, mechanical blade scraper systems, shaking pan arrangements, as well as other equipment, have been used to move material to the recycling system. No mechanical floors were evaluated for inclusion in this report.

2.2 Recycling Systems

The blasted material is cleaned and classified by the recycling system. The recycling system must remove both over and undersized material from reusable media. It must also remove contaminants such as silica and iron particles, (which may damage the substrate) and return only clean properly sized media to the blast vessel. Most commercially available recycling equipment uses the difference in density between media and contaminants/debris to effect the separation. Density is a combination of two variables; size and mass. A separation process based on density consists of two separations in series; a mass separation and a size separation. Contaminants tend to be more dense than the plastic media.

Separations based on mass apply a constant acceleration to the particle stream to effect a density based separation. Separations based on size are best accomplished using a vibrating screen, however, a stationary screen may be applicable in some cases.

A flotation method could also be used to separate reusable media from hard particles and other debris. This method would use a liquid (freon, thallium formate, or even water) to separate material based on density. This method may be used as a batch type operation when the media exceeds 0.02 percent (by weight) contamination from hard particles. The Air Force suggests that contamination exceeding 0.02 percent may cause substrate damage. The reusable media must be thoroughly dried before reintroduction to the blast vessel. This method of separation is used in the mining industry and is theoretically possible for the PMB application.

Recycling systems typically consist of a cyclone separator for removal of dust and fines from the heavier media and paint chips. They then use a vibrating or stationary screen for isolation of reusable media between 12 and 60 mesh in size.

Material is pneumatically conveyed to the cyclone separator. Particles suspended in the gas flow enter the cyclone tangentially and are then directed in a downward helical path. Centrifugal and inertial forces cause larger, heavier particles to migrate against the gas flow to the cyclone walls and continue downward until they exit at the bottom of the cyclone. The gas traveling down the outer walls of the cyclone returns in an inner spiral to the top of the cyclone and exits; carrying undersized particles with it. This gas stream is then typically cleaned by a dust filter unit.

In typical cyclone separators, 10 percent (by weight) of particles three times larger than the specified cut point (60 mesh) continue in the gas stream to the dust collector. As much as 10 percent (by weight) of particles three times smaller than the specified cut point exit the bottom of the cyclone with the properly sized media.[1]

Some second generation PMB equipment also applies a type of air knife arrangement to further prevent carryout of properly sized media and enhance fines separation. A thin knife of air is introduced into the system perpendicular to the flow of material. The air removes any remaining fines from the material stream. In some systems the amounts of air flow available to create this knife effect is adjustable. An adjustable air flow allows the cut point to be varied, as required, for the application.

Material exiting the cyclone separator (and air knife when used) is usually classified by a stationary or vibrating screen. A stationary screen only provides a means to collect oversized material. A stationary screen is adequate in systems where there is very little undersized material exiting the cyclone separator/air knife arrangement. Most systems, however, utilize a vibrating screen to remove both undersized and oversized particles. Material enters the vibrating screen at the center of the top screen. The vibration pattern of the screen is usually a vertical circle produced by an unbalanced shaft. The device uses nesting screens of decreasing size to effect several simultaneous classifications. Other vibration patterns are effected by rotating a horizontal shaft with an unbalanced flywheel. Counterweights on the fly wheel can be adjusted to control the vibrational amplitude. The vibrating action of the screen moves material toward the outer perimeter of the screen. Oversized material is automatically removed from the screen through the oversize discharge spout. Media of the desired size range is retained on the second screen and travels to a discharge that directs it to the blast vessel for reuse in subsequent blasting operations. Undersized media (less than 60 mesh) exits through the bottom discharge spout.

Recycling systems usually include a magnetic separator to remove ferrous particles from the system. Some separators require periodic manual cleaning; others reject the collected magnetic debris automatically during normal operation. No definitive design criteria have been established for this equipment.

Particles of silica sand or other non-magnetic material that become entrained in the plastic media will not be removed by traditional media recycling equipment. These contaminants are about the same size as the plastic media but are denser. These particles are also harder than plastic media and may damage substrates during PMB blasting operations. The Air Force suggests that media contaminated by more that 0.02 percent by weight of hard particles may cause substrate damage.

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1 Naval Civil Engineering Laboratory. Contract Report CR 87.001: Economic Analysis for Recycling Plastic Media: Final Report. Camarillo, CA, Engineering Management Concepts

Most hard particle contamination can be attributed to sand and dirt. Good housekeeping practices such as washing components before blasting and preventing dirt and sand from entering the system will minimize hard particle contamination.

Hard particle removal systems, in addition to the recycling equipment, have been suggested to reduce hard particle contamination in media. One of the systems uses freon as the flotation liquid and cleans the media in a flotation sluiceway. Freon is used because of its density. Plastic media particles will sink in water but will float in freon. The denser contaminants sink to the bottom. Cleaned plastic media is recovered and heated in a rotary screw conveyor to evaporate the remaining freon. Although effective, the environmental sensitivity of freon prevents its use as a commercial floatation agent. The liquid is also extremely expensive. Other separation techniques are in the process of being developed.

2.2.1 Theoretical Performance of Recycling Systems

The performance of the recycling system is constant when provided with constant air and material flow rates. An improperly designed or sized system tends to reject a constant percentage of reusable media from the material flow passing through the system. This loss not only occurs once per media blasting task, but each time the media passes through the system.

The compounding effect of media losses has been expressed mathematically as:

$$V = C^n \qquad (1)$$

where V = ratio of the amount of media remaining after completion of the blasting task to the initial media charge in the system.

C = ratio of the amount of media remaining after one cycle through the system to the amount of media in the system at the start of that pass.

n = number of passes through the system that were required to perform the blasting task.[2]

According to equation (1) the number of times the media must pass through the system to accomplish the blasting task (n) is determined by the percentage of media remaining after completion of the blasting task (V).

The value of C is the product of the percentage of usable media that is recovered from each individual component that handles material in the system. Variables that influence the value of C follow.

1. The blasting process. Media degrades into dust each time it impacts a surface. This variable is not a function of equipment efficiency or system design.

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2 Naval Civil Engineering Laboratory. Contract Report CR 87.001: Economic Analysis for Recycling Plactic Media: Final Report. Camarillo, CA, Enginering Managment Concepts

2. The recycling system. The efficiency of the recycling system depends on the efficiency of each individual piece of equipment; including the floor recovery system (not addressed in this report), cyclone separator, screening system, and other system components.

3. The PMB booth ventilation system. The ventilation system is not part of the recycling system per se, however, media can be blown into ventilation exhaust ducts and then carried to the dust collector.

Modifying the design of any of the recycling system components to recover more usable media would increase media life in the system. A mathematical relationship has been derived, using equation (1), to quantify the increased life of the media during the entire blasting operation when the amount of media recovered during each pass is increased.

Assume that the system is operating at some constant C. Now increase the ratio of usable media recovered after one pass to C' by enhancing the performance of one of the components. The amount of media remaining after the entire task is completed (V) stays constant, however, n increases with the increase in C, and the useful life of the media increases.

Mathematically stated:

$$C^n = V = C'^{n'} \tag{2}$$

The relative increase of media life in the system is calculated by solving equation (2) for the ratio of n' to n.

$$\frac{n'}{n} = \frac{\ln (C)}{\ln (C')} \tag{3}$$

3.0 WALK-IN BOOTH AT NAVAVNDEPOT PENSACOLA, FLORIDA

The walk-in booth at NAVAVNDEPOT Pensacola, Florida is used for removing coatings from aircraft and helicopter components. Zero Manufacturing Company designed and constructed the blasting booth and also manufactured the components of the media recycling system.

3.1 Description of Plastic Media Blasting System

The entire PMB system, including the blast booth, blasting equipment, recycling equipment, ventilation equipment, and baghouse is housed inside building 606 at the NAVAVNDEPOT. A flow diagram of the PMB system is shown in figure 1. A handheld nozzle is used to direct media onto the small parts and components positioned in the booth. The booth is equipped with a pneumatic full-floor recovery system. A series of collection hoppers run lengthwise under the floor to collect the blasted material and direct it into pneumatic ducting. The air flow in each of ten runs of pneumatic ducting is alternated by an electronic switching system so that only two runs have air flow at any one time. The switching system sequentially controls a series of air solenoid valves on the ducting outlets that connect to a common header.

A single cyclone fan provides the required air movement to carry the media and dust from the booth floor through the recycling system to the fabric filter dust collector (baghouse). Air flow is controlled by a damper between the cyclone and the baghouse. Another small air damper is located in the header for the pneumatic floor ducting to control air flow through the floor. Material is partially classified in a cyclone separator. The coarse media fraction exits the bottom of the cyclone and falls to a vibrating screen. The cyclone fines are routed to the baghouse for further cleaning. The baghouse exhausts directly into building 606 and is dispersed by the normal ventilation system of the building.

3.2 Automatic Floor Pick-Up System

The walk-in booth has a separate media collection hopper for each square foot of floor except for a one foot wide section at the wall line near an access door. Ten lengthwise pneumatic ducts each handle the flow of 19 hoppers. Hoppers near the access door are furthest from the common header and occlude when the cyclone fan damper is not adjusted correctly.

The system is designed to provide minimum acceptable velocities throughout the duct work. The outlet at the bottom of each of the hoppers is sized to allow sufficient media flow and to minimize plugging. The ducting and hopper outlets are also sized to use the angle of repose of the media falling from the hopper. Media falls through the outlet and forms a cone that does not completely block the duct. Airflow over th media cone is sufficient to continuously transport material from the cone until the hopper is emptied and the cone is gone.

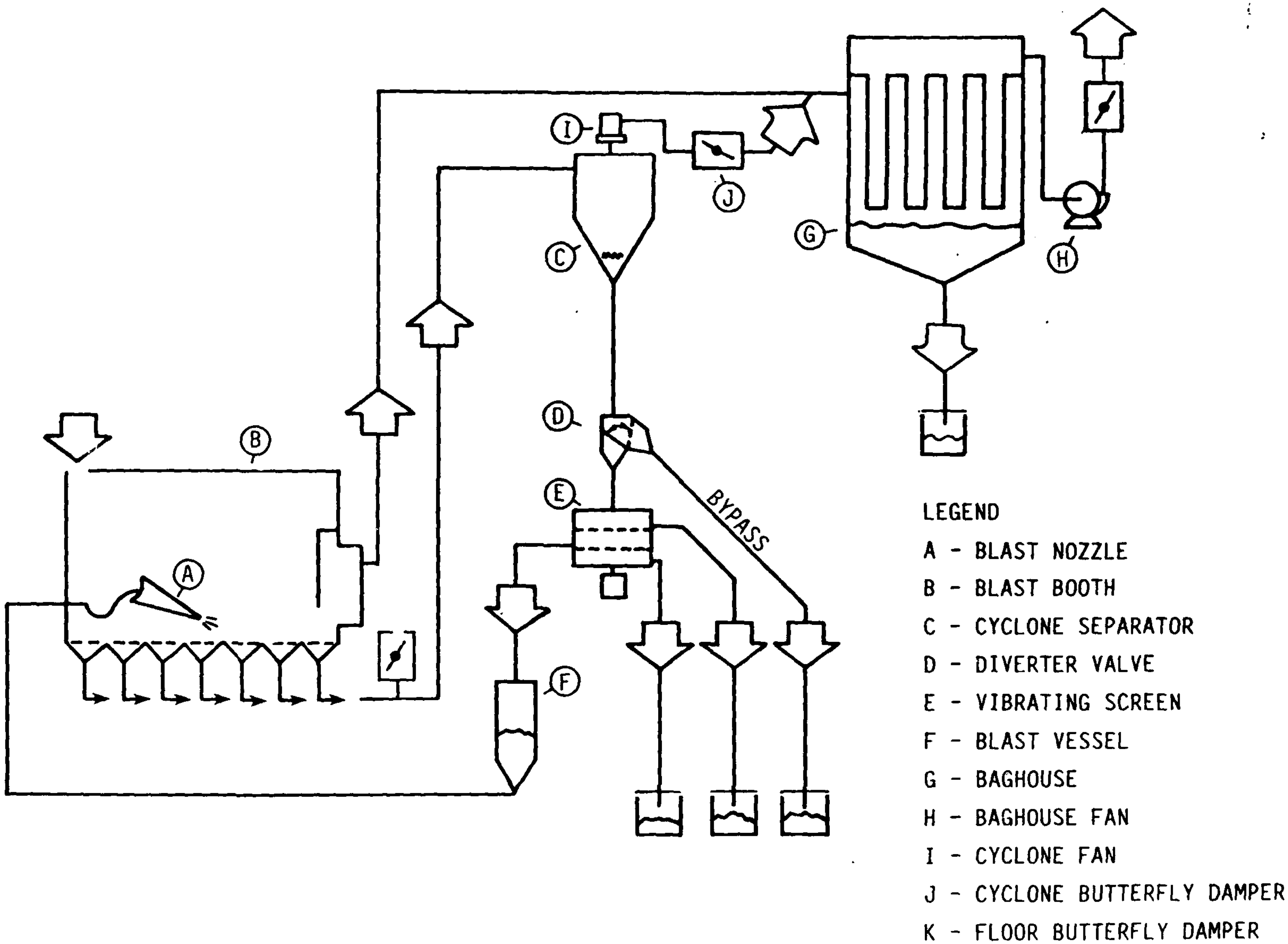


Figure 1. Walk-in Booth at NAVAVNDEPOT Pensacola.

The sequential air flow in the ducts lessens the overall system flow requirements, minimizing the size and cost of the system. An electronic switching system operates a series of quick opening solenoid valves that control the airflow from each duct into a common header. Only two of the ten duct valves are opened at any one time, so full suction and air flow is provided to these ducts. The size of the subsequent ducting, cyclone, and cyclone fan is only 20 percent of the size that would be required to operate all the ducts simultaneously. The size of the baghouse is also reduced. The floor pick-up system, as currently operated, represents only about 10 percent of the total air flow to the baghouse; the rest comes from the ventilation system.

The system was designed to operate with an air flow of approximately 1100 cubic feet per minute (cfm) through the floor, however, the floor is operating at about 820 cfm. Actual measurements and calculations are provided in Appendix A. 820 cfm is the minimum air flow found to be operationally effective. Air flow greater than 820 cfm increases the amount of media rejected from the cyclone.

3.3 Cyclone Separator

The cyclone separator rejects a large percentage of reusable media in the fine fraction directed to the baghouse. The air flow from the floor has been reduced to 820 cfm in order to minimize (but not eliminate) the carryover of good media from the cyclone. Further reduction in the air flow rate results in the plugging of the floor pick-up system.

Cyclone performance was evaluated using two separate methods. The first method required the collection of a sample of dust laden air exiting the top of the cyclone during actual blasting operations and subjecting it to a particle size analysis. In the second method, new media was weighed and introduced to the recycling system. The amount of media returned as recycled media was then determined. Results of both test methods indicate that large amounts of usable media escape from the recycling system and are routed to the baghouse for disposal as hazardous waste.

3.3.1 Particle Size Distribution Analysis

The results of the particle size analysis of the cyclone reject material are shown in table 1. New media added to the system over a period of several days had been in the 30 to 40 mesh size range. The method of sample collection did not disturb normal cyclone operation.

Table 1. Particle Size Distribution of Cyclone Reject at NAVAVNDEPOT Pensacola Walk-in Booth

Mesh Size	Weight Percent of Media
0 - 12	0.0
12 - 60	60.7
60 - 100	26.8
100 - 200	8.7
> 200	3.8

This analysis indicated that approximately 60 percent of the material rejected from the cyclone was in the 12 to 60 mesh size range and was, therefore, considered to be reusable media.

3.3.2 Bulk Media Loss Analysis

The second test added 21 pounds of new 12 to 16 mesh plastic media to the floor recovery system with no other media circulating. The media was processed through the cyclone at normal system air flows and only 18 pounds of media were reclaimed by the cyclone. The test indicated that 3 pounds, or 14 percent, of the media was rejected from the cyclone and directed to the baghouse. Estimating the media losses at 14 percent is conservative as heavier 12 to 16 mesh particles were used in the test. Cyclones classify particles by mass. Average particles in the 30 to 40 mesh range weigh about 20 times less than 12 to 16 mesh particles, and the cyclone should be expected to discard a higher percentage of these smaller particles.

3.3.3 Effects of Usable Media Losses in the System

Media is lost, through degradation, during the blasting process (see paragraph 2.2.1). At NAVAVNDEPOT, this loss is about 6 percent (by weight) of the amount of media available for that pass. This loss occurs with each pass through the system. The ventilation system did not trap an appreciable amount of media. The recycling equipment, in particular the cyclone separator, was responsible for the greatest amount of media loss and is the subject of the following analysis.

An accurately sized cyclone designed to maximize usable media recovery will have a concentration of about 10 percent usable media in the undersized fraction discarded to the baghouse. The particle size analysis described in paragraph 3.3.1 can be combined with the 14 percent loss determined in paragraph 3.3.2 to calculate the expected percentage of usable media loss from an adequately sized cyclone.

The particle size analysis indicated the cyclone was discarding approximately 60.7 percent usable media and 39.3 percent undersized material and paint dust. If the test had been conducted with the typical concentration of undersized material present, then 39.3 percent of the 3 pounds rejected from the cyclone, or about 1.2 pounds of undersized material, would have been collected to maintain the 60.7 percent to 39.3 percent ratio. If an adequately sized cyclone was used, the weight percent of usable media collected would then have been 10 percent of the total material collected. The cyclone, therefore, would have rejected only 0.13 pounds of the 21 pounds used in the test, or about 0.6 percent of the usable media being passed through the system. These calculations are presented below.

1. Particle analysis shows 39.3 percent of cyclone reject material is under 60 mesh. Total cyclone reject material during the test was 3 pounds.

   Weight of undersize reject material is 39.3 percent of 3 pounds which equals 1.2 pounds.

2. In an adequately sized cyclone, 10 percent of the weight of rejected material is oversized (reusable media greater than 60 mesh). The 1.2 pounds of undersized material is, therefore, 90 percent of the total weight of rejected material. Weight of the 10 percent reusable media fraction is:

$$\frac{\text{1.2 pounds undersized material}}{0.9} \times 0.1 = \text{0.13 pounds of usable media.}$$

3. Theoretical loss of usable media during test should have been 0.13 pounds of the 21 pound (lb) sample.

   Theoretical usable media loss = 0.13/21 = 0.6 percent.

An adequately sized cyclone at the NAVAVNDEPOT Pensacola facility could reduce the usable media losses in the cyclone to 0.6 percent from the present loss of 14 percent. The effect of this change on the overall system can be quantified using equation (1).

Observations of the system indicated that the overall media losses in the blasting process, vibrating screen, and ventilation system were minimal when compared to the cyclone. Media degradation was about 6 percent (by weight). For comparison purposes, set the ventilation and screen recovery factors to 100 percent to evaluate the effect of an adequately sized cyclone.

The media recovery percentage with the existing cyclone, C, is:

$$C = (1 - \text{Degradation losses}) \times (1 - \text{Cyclone losses}) \times 100$$
$$C = (1 - 0.06) \times (1 - 0.14) \times 100 = 81 \text{ percent}$$

The media recovery percentage with an adequately sized cyclone, C′ is:

$$C' = (1 - 0.06) \times (1 - 0.006) \times 100 = 93 \text{ percent}$$

Solving equation (3) for the relative increase of media life in the system:

$$\frac{n'}{n} = \frac{\ln (C)}{\ln (C')} = \frac{\ln (.81)}{\ln (.93)} = 2.9$$

This ratio states that because less media is being lost in the cyclone, the number of times that a fixed amount of media is recycled through the system to perform a specific task is about a third of the cycles required when higher losses were occurring in the cyclone. Thus, the amount of replacement media could also be cut to a third of the existing media requirements. An economic study should be performed to verify these savings. Figure 2 is a graphical representation of the relative media losses over time for both an adequately sized cyclone and the existing cyclone. The curve labeled Existing Cyclone shows the accelerated media depletion caused by the inefficiency of the cyclone.

Standard cyclones are available to handle the design requirements of this system. A properly sized cyclone is shown in figure 3. The unit is sized to accommodate flow rates and densities encountered on-site. The new unit has the same 3 foot diameter as the existing unit, but is over 10 feet long as compared to the present length of only 2 1/2 feet.

3.4 Vibrating Screen

Reusable media exiting the bottom of the cyclone is further classified by the vibrating screen to remove oversize paint chips and undersize material not removed by the cyclone.

The vibrating screen is pressure sealed by a hemispherical diaphragm under the second screen. The entire unit is operated under a slight vacuum to control dust. To maintain the vacuum, covers are placed on the undersized and oversized material collection drums.

The effectiveness of the screen, represented by the particle size distribution in each of the discharge streams, is detailed in table 2.

The oversized stream is over 70 percent usable media in the 12 to 60 mesh range, however, observation indicates that the flow rate of this stream is low and media losses are not appreciable when compared to media lost by the cyclone. Decreasing the mesh size of the existing screen (thereby slightly increasing the hole size to pass more media through to the second screen) would help minimize media losses.

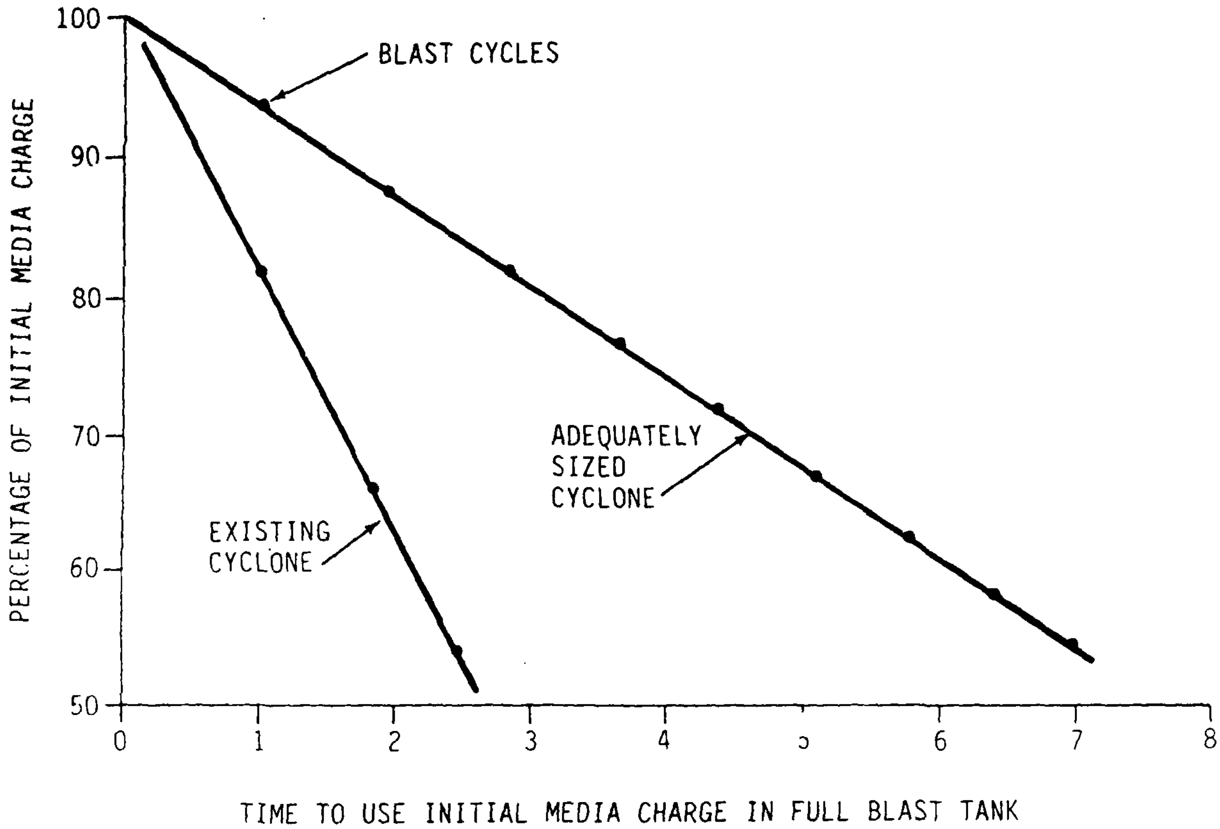


Figure 2. Relative Rates of Media Depletion at NAVAVNDEPOT Pensacola Walk-in Booth.

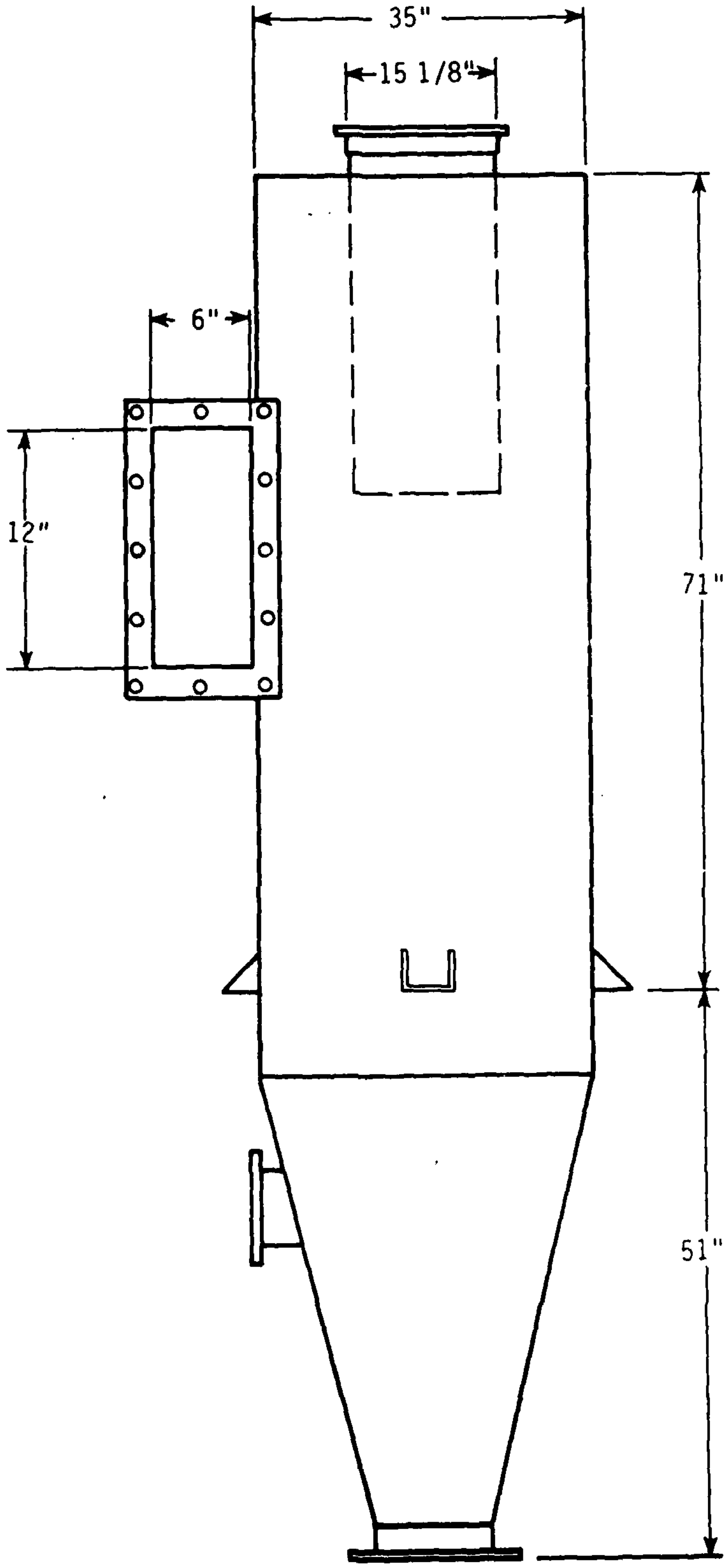


Figure 3. Typical Cyclone Classifier.

Table 2. **Particle Size Distributions of Vibrating Screen Discharge at NAVAVNDEPOT Pensacola**

Mesh Size	Oversized (Weight Percent retained by top screen)	Recycled Media (Weight Percent retained by bottom screen)	Undersized (Weight Percent passing through both screens)
0 - 12	25.6	0.1	0.0
12 - 60	73.2	95.7	0.1
60 - 100	0.5	4.2	44.7
100 - 200	0.6	0.0	49.4
> 200	0.6	0.0	5.8

The bottom screen retains over 4 percent undersized media. Other PMB installations have screens that retain less than 0.5 percent of undersized media. The introduction of undersized material to the blast vessel decreases blasting efficiency and increases dust levels in the booth.

3.5 Ventilation

Cross draft ventilation in the blast booth is provided by the baghouse induction fan. Fresh air enters the booth through a duct in the ceiling opposite the fan. The forward motion of the air effectively removes dust from the work area. The ventilation rate can be adjusted with a manual damper located at the discharge of the baghouse fan. The present damper setting uses only 55 percent of the rated fan capacity.

The air flow rates through the booth were determined to be 7,300 cfm. Appendix A identifies test procedures and provides detailed calculations to determine air velocities. The cross-sectional velocity through the 10 ft wide by 12 ft high booth is approximately 60 feet per minute (fpm). This air velocity provided excellent visibility in the work area and quickly removed dust from the room. If needed, the air velocity could be increased by fully opening the baghouse fan damper.

Exhaust ducts in the booth are protected by box-like covers with baffled sides to minimize the amount of media blown directly into the ventilation system during blasting or clean up. Some media may still be introduced into the ventilation system, so a gravity settling chamber is installed upstream from the baghouse near the exhaust duct exit from the booth. The slower air velocity through the chamber allows larger media particles time to settle out of the ventilation air stream and be recovered. A minimal amount of media is reaching the baghouse through the ventilation system. This combination of baffled exhaust covers and a gravity settling chamber effectively minimizes reusable media losses from the ventilation system.

3.6 Baghouse

Dust filtration is provided by a reverse pulse-jet fabric filter baghouse. The baghouse filters air flows from the cyclone and the booth ventilation systems. Air flow through the baghouse was about 8,100 cfm, giving an air-to-cloth ratio of about 2.4 cfm per square foot of filter area. The system was adequately sized and released no visible dust in the exhaust.

Since the baghouse exhausts directly into building 606, any potentially harmful gasses or dust generated by the PMB process that are not captured by the baghouse are discharged into the building.

3.7 Conclusions

The overall performance of the floor pick-up system was excellent. Observations, tests, and discussions with blast operators verify that the floor system adequately removes media from the blasting area and conveys it to the recycling equipment. The media is effectively removed with a minimum of operator assistance. The sequential operation of the ducts minimizes the size of other recycling system components and helps to minimize floor plugging.

The current cyclone is undersized and causes approximately three times the amount of reusable media to be discarded compared to an adequately sized cyclone.

The vibrating screen returns essentially all of the reusable media stream to the blasting equipment. The top screen holes need to be slightly increased in size to capture the reusable media now being retained and discarded off the top screen.

The ventilation system effectively removes dust from the work area and minimizes the loss of usable media to the baghouse using a baffled cover in conjunction with the separator box. The baghouse filter effectively captures dust from the ventilation and cyclone exhaust.

4.0 WALK-IN BLAST BOOTH AT HILL AFB, OGDEN, UTAH

The small parts walk-in blast booth at Hill AFB is primarily used to strip paint from aircraft components. The booth is approximately 15 ft wide by 30 ft long by 10 ft high. It is equipped with blasting equipment manufactured by CABER, Incorporated.

4.1 Description of Plastic Media Blasting System

A flow diagram of the PMB system is shown in figure 4. Media is recovered from the floor by shoveling or sweeping it into a pit located in one corner of the booth. An induction draft fan conveys the used media from the pit to the air classifier. Air flow is adjusted with a damper installed at the fan discharge. The fine fraction from the air classifier is routed to the baghouse filter. The coarse media cut passes through a rotating valve onto the screen. The rotating valve isolates the air classifier vacuum from the vibrating screen classifier and meters material onto the screen.

Oversized paint chips and other debris retained on the top screen and the undersized media and dust falling through the second screen are collected for disposal in the same drum. The properly sized media retained on the second screen is routed to a storage vessel after passing through a magnetic separator to remove magnetic fragments. Ventilation is provided by a baghouse induction fan that returns process air to the booth. Booth temperature is controlled by the addition of fresh air, as needed.

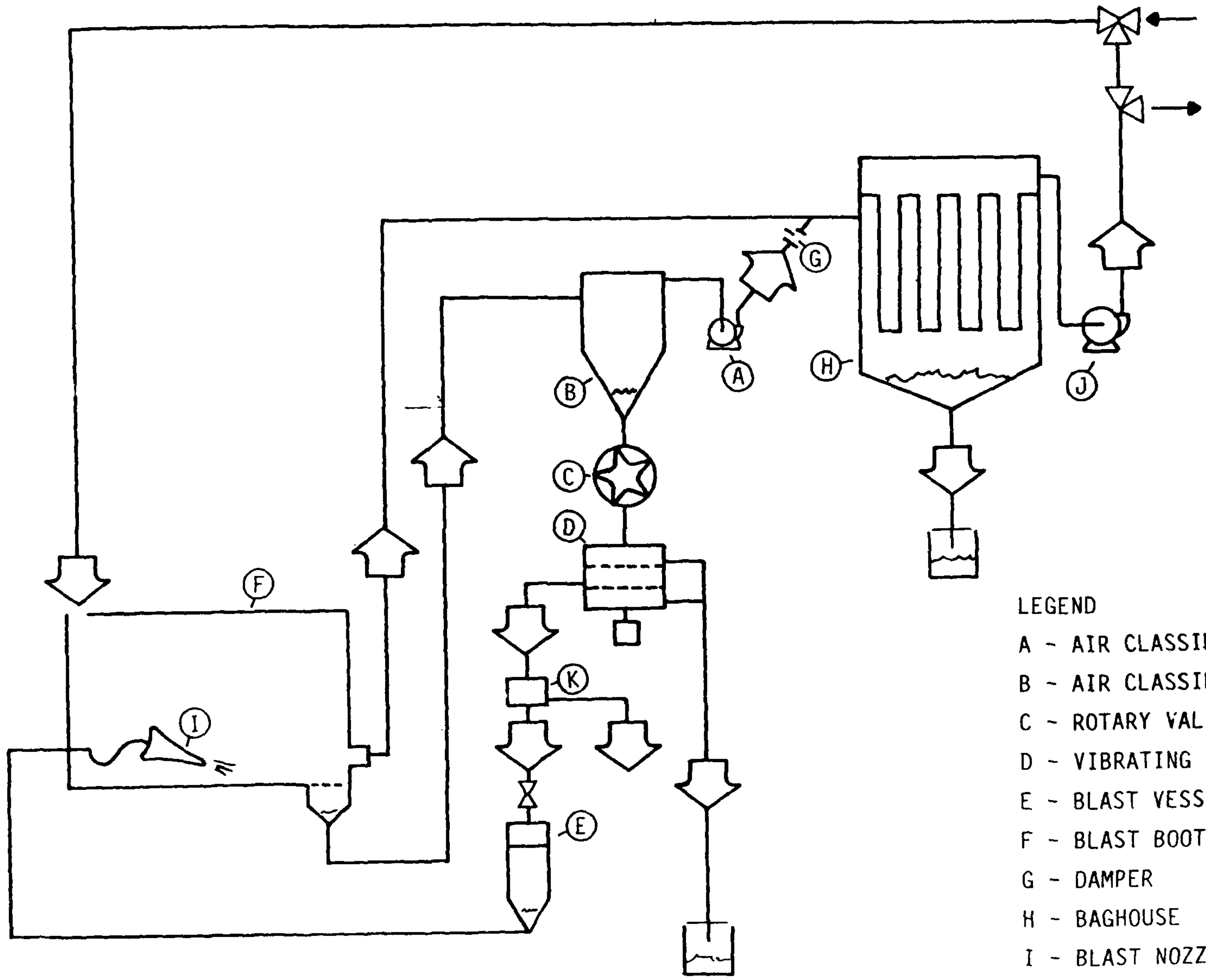
4.2 Floor Pick-Up System

Operators stand on a solid, steel, diamond plate floor while blasting. Spent media, dust and paint chips settle and accumulate on the floor. When media accumulation on the floor becomes too high or when the blast vessel exhausts its media supply, the media is manually shoveled and/or swept into the recovery pit.

Observations indicate that nearly half of the overall operating time is given to clean up. Despite the time required for the clean up effort, the overall labor requirements are still much less than for the chemical methods of paint removal previously utilized.

4.3 Air Classifier

The dust laden air is routed through the air classifier to the baghouse; the media exits the bottom of the classifier and passes through a rotating valve to the vibrating screen. Rotary valves are normally specified when pressure or vacuum isolation is required and/or when limits on the rate of feed to down stream equipment are advantageous. Rotary valves utilize pressure isolating blades that require periodic adjustment and replacement due to normal wear. Blade wear is accelerated when using abrasive blasting media. Rotary valves are typically high maintenance items.



LEGEND

A - AIR CLASSIFIER FAN
B - AIR CLASSIFIER
C - ROTARY VALVE
D - VIBRATING SCREEN
E - BLAST VESSEL
F - BLAST BOOTH
G - DAMPER
H - BAGHOUSE
I - BLAST NOZZLE
J - BAGHOUSE FAN
K - MAGNETIC SEPARATOR

Figure 4. Walk-in Booth at Hill AFB.

The air classifier, despite the addition of an adjustable damper, allows a large percentage of properly sized material to carryover to the baghouse. The manufacturer's fan curve and measured pressure differentials indicate that the air flow through the air classifier is about 550 cfm. Evaluation of classifier performance was accomplished using the same methods detailed in paragraph 3.3.

4.3.1 Particle Size Distribution Analysis

Samples of dust rejected from the air classifier were collected during blasting. It was difficult to obtain a sample representative of the true size distribution of the discharge stream because the classifier fan discharge ducting is under pressure. Care was used to obtain a representative sample and to insure that both high and low mass particles were captured. The system was charged with a mix of both new 30 to 40 mesh media and recycled media. Table 3 presents the particle size distribution of the sample.

Table 3. Particle Size Distribution of Air Classifier Reject at Hill AFB Walk-in Booth

Mesh Size	Weight Percent of Total Sample
0 - 12	0.0
12 - 60	28.0
60 - 100	7.8
100 - 200	28.2
> 200	36.0

4.3.2 Bulk Media Loss Analysis

A measured amount of new media was introduced into the floor pick-up pit and was recovered as it exited the vibrating screen. The sample could not be collected directly from the air classifier discharge because of the system design. Since new PMB material was used for this test (smallest particle size was 40 mesh), it can be assumed that the vibrating screen did not reject any media. This assumption was verified by placing a collection container over the screen oversize and undersize reject discharges during the efficiency test. The very small amount of material collected was negligible when compared to the amount correctly classified and was ignored in this analysis. 102 pounds of new 30 to 40 mesh media was added into the media recovery pit; 93.5 pounds were recovered. 8.5 pounds, or about 8.5 percent, of the total media charge, was rejected from the cyclone.

4.3.3 Effects of Usable Media Losses in the System

The estimated loss from an adequately sized cyclone or air classifier that discharges only 10 percent (by weight) usable media in the undersized fraction has been calculated. The air classifier rejected 28 percent (by weight) of 12 to 60 mesh media and 72 percent (by weight) undersize material. If the test had been conducted with the typical concentration of undersized material present, then 72 percent of the 8.5 pounds, or 6.1 pounds, of undersized material would have been collected. If an adequately sized unit was used, the weight percent of usable media collected would then have been 10 percent of the total material collected. The cyclone would, therefore, have discarded only 0.7 pounds of the 102 pounds used in the test or about 0.7 percent of the usable media being passed through the system. Calculation of percent loss of usable media from adequately sized cyclone follows.

1. Particle analysis shows 72 percent of the air classifier reject material is under 60 mesh. Total cyclone reject material during test was 8.5 pounds.

   Weight of the undersize reject material is 72 percent of 8.5 pounds which equals 6.1 pounds.

2. In an adequately sized unit, 10 percent of the weight of rejected material is oversized (reusable media greater than 60 mesh). The 6.1 pounds of undersized material is, therefore, 90 percent of the total weight of rejected material. The weight of the 10 percent reusable media fraction is:

$$\frac{6.1 \text{ pounds undersized material}}{0.9} \times 0.1 = 0.7 \text{ pounds of usable media.}$$

3. Theoretical loss of usable media during test should have been 0.7 pounds of the 102 pound sample.

   Theoretical usable media loss = 0.7/102 = 0.7 percent.

The replacement of the existing air classifier with a larger sized unit can theoretically reduce usable media losses from 8.5 percent to 0.7 percent. The relative reduction of operating costs from this change can be estimated using equation (1).

Media degradation due to the blast impact was approximately 5 percent. Screen losses (described in paragraph 4.4) were about 1 percent. The amount of usable media introduced and subsequently lost to the ventilation system was not quantified. Losses to the ventilation system are possibly the largest source of media loss in the process, however, these losses were not considered in the following analysis. To evaluate the effect of an adequately sized cyclone the screen recovery factor is assumed to be 100 percent.

The media recovery factor for the existing air classifier and screen, C, is:

$$C = (1 - \text{Degradation Losses}) \times (1 - \text{Classifier Losses}) \times (1 - \text{Screen Losses}) \times 100$$

$$C = (1 - 0.05) \times (1 - 0.085) \times (1 - 0.011) \times 100 = 86 \text{ percent}$$

The media recovery factor for an adequately sized unit, C′, is:

$$C' = (1 - 0.05) \times (1 - 0.007) \times (1 - 0.011) \times 100 = 94 \text{ percent}$$

Solving equation (3) for the relative increase of media life in the system;

$$\frac{n'}{n} = \frac{\ln (C)}{\ln (C')} = \frac{\ln (.86)}{\ln (.94)} = 2.4$$

This ratio states that because less media is being lost in the cyclone or air classifier, the number of times that a fixed amount of media is recycled through the system to perform a specific task is less than half of the cycles required when higher losses were occurring in the air classifier. The amount of replacement media could, therefore, also be reduced by about 50 percent of the existing media requirements. An economic study should be performed to verify these savings. Figure 5 is a graphical representation of the relative media losses over time for both an adequately sized cyclone and the existing classifier. The curve labeled Existing Classifier shows the accelerated media depletion caused by the inefficiency of the classifier.

4.4 Vibrating Screen

The vibrating screen is the same design as the unit at NAVAVNDEPOT Pensacola, except that it does not operate under a vacuum. Table 4 presents the particle size distribution of media rejected from the vibrating screen undersized particle discharge. The oversized discharge contained only a few small paint chips; usable media loss is considered negligible.

Table 4. Particle Size Distribution of Usable Media from the Vibrating Screen Discharge at Hill AFB Walk-in Booth

Mesh Size	Weight Percent of Total Sample
0 - 12	0
12 - 60	39.3
60 - 100	46.6
100 - 200	11.2
> 200	2.9

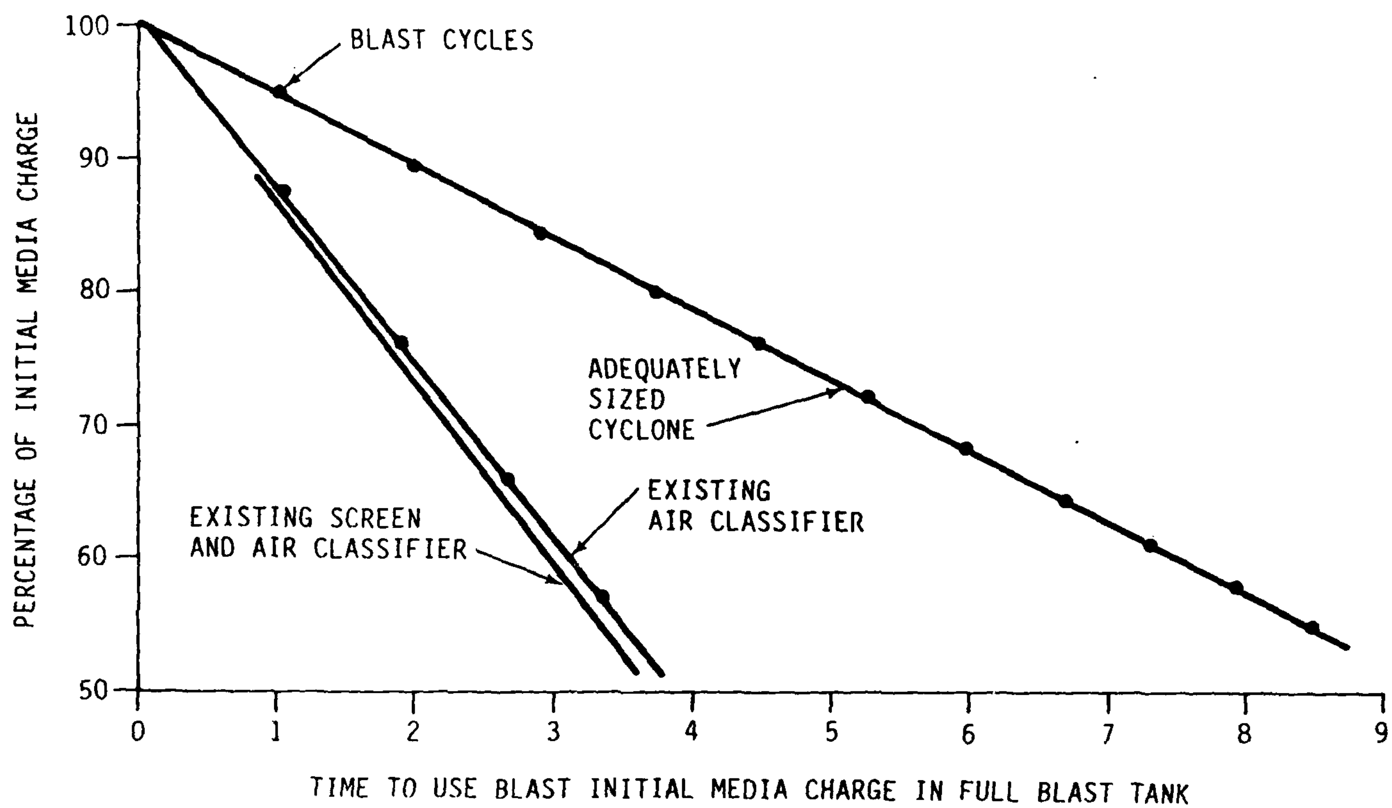


Figure 5. Relative Rates of Media Depletion at Hill AFB.

The material in the undersized material discharge contains over 39 percent reusable media in the 12 to 60 mesh range. In order to quantify good media losses, mass flow rates were measured and the percentage of usable media lost through the undersized discharge is calculated. Mass flow from the undersized discharge was 0.91 pound of material per minute. Mass flow of the properly sized, recycled media, to the blast tank was 30.5 pounds per minute.

The percentage and actual amount of usable media lost through the undersized screen is calculated below:

$$(0.393) \times \frac{(0.91 \text{ lb/min})}{(30.5 \text{ lb/min} + 0.91 \text{ lb/min})} \times 100 = 1.1 \text{ percent}$$

$$(0.393) \times (0.91 \text{ lbs/min}) = 0.36 \text{ lbs/min}$$

A given media charge is recycled many times. One percent of this charge is lost each time it passes through the screen so the compounded media loss for a given charge may approach 15 to 20 percent.

4.5 Magnetic Separator

Media with a proper size distribution for recycle exits the vibrating screen and passes through a magnetic separator and into the blast vessel (see figure 4). Ferrous and other materials collected by the magnetic separator must be manually removed from the magnets in the separator box.

The active area of the separator consists of a series of bar magnets installed horizontally, in the same plane, across the inlet. This configuration allows only one opportunity for ferrous materials to be caught by the magnets. Long and fine materials adhere to the magnet surfaces in a wire-brush like configuration. The amount of ferrous material retained is minimal because the action of the media falling quickly past the magnets has the tendency to sweep particles from the magnets. Still, considerable paramagnetic material was collected in the unit despite this design inadequacy. The separator was cleaned at the start of a shift and normal operations commenced. On the following day, the sample removed from the full separator weighed 0.048 lbs. Over 90 percent of the sample was in the 12 to 60 mesh range indicating that the separator is only effective in removing larger steel particles. Smaller sized particles were brushed from the magnetic bars by the passing media.

The orientation of the magnetic bars and the orientation of magnetic debris trapped on them tend to collect a blend of material. The specific gravity of material removed from the magnetic separator was 2.41. Iron has a specific gravity of about 8; indicating that the material trapped by the separator is not strictly iron. Metal analysis indicated that 20 percent of the sample was iron.

Baghouse samples contained an iron concentration three times as high as samples collected from the floor. High iron concentrations in the baghouse suggest that a large amount of iron is of a small particle size. A large portion of this iron is probably present as iron oxide (a pigment used in paint). A magnetic separator would not be effective in removing this type of iron contamination, nor is it necessary to do so. A metals analysis indicates that a sizeable amount of lead and nickel are present in the sample collected from the magnetic separator. Nickel is not present in samples collected elsewhere in the recycling system. The mechanism which traps the nickel in the magnetic separator is not understood.

4.6 Ventilation

Ventilation in the blast booth is provided by the baghouse induction fan that draws air from the booth through two exhausts. The exhausts are located at the front of the booth near the floor. The exhaust air is routed to a baghouse for particulate removal and is recirculated to the booth through two supply ports located on the ceiling of the booth. Temperature control in the booth is maintained by dampers which vary the exhaust of the recycled air to atmosphere and the intake of fresh air into the system.

The recycled, temperature-controlled air provides primarily crossdraft ventilation with a slight downdraft as it flows from the inlets to the exhausts. This air flow pattern effectively removes dust from the work area. The air flow rate was measured to be 9300 cfm. The cross-sectional flow rate through the 15 ft wide by 10 ft high area is, therefore, about 61 fpm. This air flow rate was sufficient to provide good visibility during blasting operations. Measured air velocities and calculations are presented in Appendix B.

One of the exhausts is located close to the media pick-up pit in the floor. Media tends to be introduced into this exhaust when the blasted material is swept toward the pit during clean-up operations. The rising air velocity in the duct is greater than the media free falling rate, so any usable media entering the exhaust is carried to the baghouse.

4.7 Baghouse

The reverse pulse-jet fabric filter unit collects the fines rejected from the top of the cyclone as well as the ventilation air. The air flow through the baghouse was measured at about 9750 cfm. The system appeared to efficiently remove dust and fine particulates with no noticeable media dust in the baghouse exhaust.

4.8 Conclusions

The floor recovery pit provides an adequate means of media recovery in a small booth that processes parts on a semi-continual basis. A full or partial recovery floor would reduce the labor necessary to recover the media and increase actual blasting time. The use of a vacuum hose is an alternate method of cleaning the floor. Vacuuming reduces dust levels and helps alleviate operator fatigue. The loss of media to the ventilation system would also be minimized. At the Hill AFB walk-in booth, a vacuum hose and hookup are available to the operators, but were not utilized during these observations. Enlarging the hookup piping and hose would increase vacuum effectiveness. To minimize vacuum losses, suction hoses should be internally smooth, as opposed to the accordion type currently used, to convey media for recovery.

The current air classifier is undersized and causes about 2.5 times the amount of reusable media to be discarded compared to an adequately sized cyclone.

The use of a high maintenance rotary valve is not as desirable as operating the entire system under pressure. NAVAVNDEPOT Pensacola successfully eliminated the rotary valve from the booth design.

The vibrating screen loses approximately 1.1 percent (by weight) of media in the 12 to 60 mesh size range. The holes in the bottom screen need to be increased slightly in size in order to pass all undersize material to the undersize reject.

The magnetic separator removes ferrous debris from the system and is necessary to remove potentially substrate damaging iron particles. The separator tends to fill quickly. It becomes ineffective unless it is emptied regularly. Other magnetic separator designs should be evaluated.

The ventilation system effectively removes dust from the work area. Exhaust ducts should not be placed near media recovery pits or troughs. Exhausts ducts should be baffled to minimize media intrusion into the ventilation system.

5.0 F-4 BLAST ENCLOSURE AT HILL AFB, OGDEN, UTAH

5.1 Description of Plastic Media Blasting System

This is the first PMB enclosure designed to process complete F-4 aircraft on a regular basis. The installation clearly demonstrates the economic and environmental advantages of PMB over chemical stripping.

Figure 6 shows the flow diagram for this large enclosure. Operators are able to blast an entire F-4 aircraft in the enclosure. A pneumatic full-floor recovery system removes plastic media and debris from the floor. The under floor area is equipped with a series of collection hoppers. Air is supplied through the hoppers to convey material to a combination baghouse/screen unit for size classification and cleaning. This air is filtered by cartidge filters and returned to the blast enclosure. Heavier PMB material falls onto a single angled screen. The screen allows lighter material to pass into a hopper collection area for disposal. Properly sized material is retained by the angled screen and falls toward outlet ducts which feed into the blast vessels. Additional ventilation is provided by a separate fan and baghouse that removes, cleans, and returns air through various exhaust and supply ducts located throughout the enclosure.

5.2 Automatic Floor Pick-Up System

Observations and discussions with blast operators indicate that the existing system provides marginal collection of the used media and debris. Some of the material is picked up automatically, but system clogging occurs in high use areas or in areas that do not experience sufficient air flow. These media accumulations are manually removed by the operators.

The floor was also designed to provide a large part of the system ventilation requirements. Due to the clogging mentioned above, the air flow through the floor is not sufficient to facilitate optimum air distribution in the enclosure.

5.3 Screen

Reusable material is separated from debris and dust in the media baghouse. The material falls against a single angled screen. Oversize material is prevented from entering the system by a separate screen installed in the floor. Fines pass through the screen and are collected in a hopper for disposal. Properly sized material is routed to outlet ducts that feed into the blast vessels. The particle size distribution for both the undersized material and recycled media streams are shown in table 5.

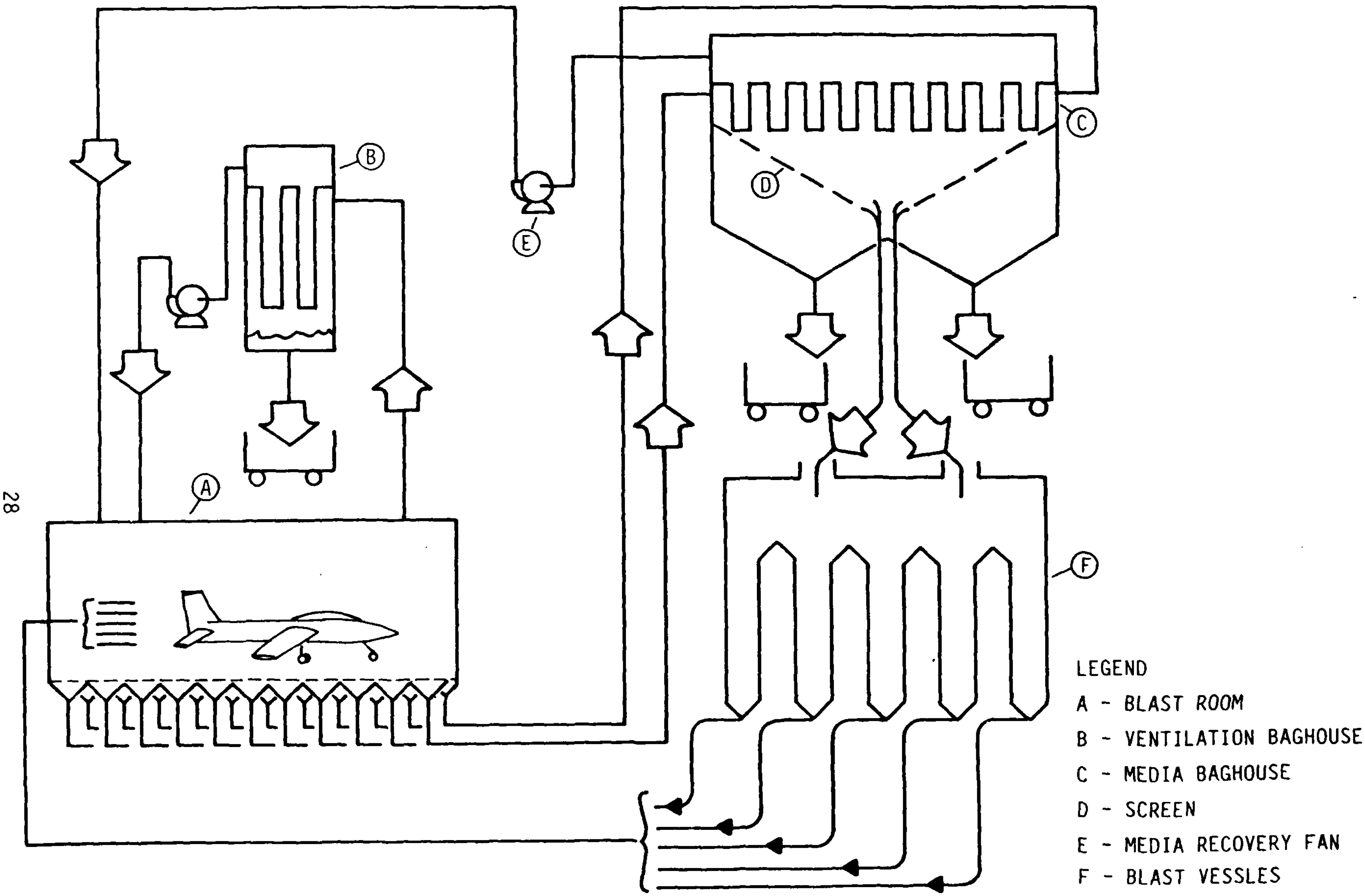


Figure 6. F-4 Blast Room at Hill AFB.

Table 5. Particle Size Distributions of Vibrating Screen Discharge at Hill AFB F-4 Room

Mesh Size	Recycled Media (Weight Percent Retained on Screen)	Undersized Material (Weight Percent Passing through Screen)
0 - 12	0.1	0.0
12 - 60	94.9	49.2
60 - 100	4.7	30.7
100 - 200	0.4	14.2
> 200	0.04	5.9

Recycled media contains a about 5 percent of undersized material because there is no mechanism available to wash this dust from the recycle stream. Reintroducing even a small amount of dust into the enclosure through the blast nozzles may exacerabate visibility problems during blasting. The high percentage of usable media passing through the screen suggests that the screen is not adequately sized for current conditions. The particle size determination indicates that half of the material discarded from the media baghouse may be reusable media.

5.4 Ventilation

Ventilation is provided by the media recovery baghouse/screen combination, previously discussed, working in conjunction with a separate, smaller ventilation baghouse system. Several inlets and exhausts are installed in the ceiling, hangar door, and opposing wall. Various configurations of inlets and exhausts have been experimented with to improve dust removal.

Ventilation is adequate when the floor recovery system is clean during the initial stages of blasting. This suggests that the air flow is sufficient for a limited number of blast operators when the floor system is clean. As the floor becomes plugged during blasting, the air flow decreases and dust is not effectively removed from the enclosure. Operator visibility is often limited by the airborne dust. The original system was designed to operate five blast nozzles, however, due to dust levels and the increased load on the floor only two or three are operated simultaneously.

5.5 Baghouses

Filter area and air flow rate data were not obtained from either baghouse. The media baghouse is operated by a reverse pulse jet cleaning mechanism and uses paper cartridge filters. The ventilation air baghouse contains bags and is about the same size as the two walk-in booth system baghouses.

5.6 Conclusions

The F-4 aircraft blast enclosure clearly demonstrates that PMB is a viable alternative to chemical paint stripping in a production setting. The equipment safely and adequately removes paint from F-4 airframes.

The pneumatic recovery floor functions as a major component of the enclosure ventilation system. The relationship between media recovery and enclosure ventilation is less than ideal. The floor hoppers become occluded due to inadequate air flow, further decreasing the air flow available for enclosure ventilation. The ventilation system was designed to utilize the floor (as exhausts) to provide a downdraft pattern. As the floor becomes increasingly plugged, the pattern is no longer one of downdraft flow; air eddies and dead zones are established. The combination of inadequate air flow and less than ideal flow patterns combine to create a dust laden working environment. Two separate systems for ventilation and media recovery would enhance the safety and efficiency of the PMB process.

The media recycling system primarily returns correctly sized material to the blast vessels. Some undersized material is also reintroduced into the blast vessels. A mechanism to wash properly sized media of the dust that adheres to it is required. A cyclone separator or other air classification device is suggested.

The angled screen is not capturing all of the media in the 12 to 60 mesh size range. Allowing properly sized media to escape recycle increases media purchase costs and also increases the amount of material that must be disposed of as hazardous waste.

6.0 PHYSICAL AND CHEMICAL CHARACTERISTICS OF PLASTIC MEDIA SAMPLES

6.1 Plastic Media Sample Collection and Analysis

The plastic media taken from the recycled media and the rejected media/dust sample points at each of the three PMB sites were collected in accordance with the Test Plan included as Enclosure 1. The sampling method did not impact system operating parameters. The samples were analyzed to determine the following physical and chemical characteristics:

1. **Particle Size Distributions.** Size distribution was determined by sieving the particles into five different size ranges. The data determined the percentage of usable media in the system rejects and in the dust found in the recycled media and, thus, the effectiveness of the media separating and recycling equipment.

2. **Specific Gravity Determination.** The specific gravity of the recycled media samples was measured and compared to the specific gravity of new media. Significant increases in specific gravity indicate contamination in the sample.

3. **Silica Concentration Analysis.** Silica in the recycled media may be a cause of mechanical damage experienced by some substrate materials. The Air Force recommends that hard particle contamination in the media be held to 0.02 percent. Samples of media and dust were analyzed for total silica concentration.

4. **Total Metal Concentration Analysis.** Samples of recycled media were analyzed for total metals content. The data will be evaluated to determine if possible health hazards exist for handlers of PMB waste materials. New media was also tested to provide baseline concentrations.

5. **Leachable Metals Concentration.** Samples of rejected media and dust were divided into several size ranges and tested for leachable metals concentrations.

Sufficient sample volumes were collected at each sample location to accomplish all of the required test procedures for each sample. Two sets of samples were taken at the Hill AFB walk-in booth in order to provide a basis for data comparison.

6.2 Particle Size Distribution

The size distribution of the particles in the process stream for the three sites are shown in tables 6 through 8. Particles in the 12 to 60 mesh size range are considered to be of sufficient size for reuse. An ideal recycling system would show the recycled media to be 100 percent 12 to 60 mesh particles. Media rejected from the recycling system would not contain any particles in the 12 to 60 mesh range. Samples collected from the floor of each site were also subjected to size distribution analyses in order to determine

Table 6. Particle Size Distribution of the NAVAVNDEPOT Pensacola Walk-in Booth

Location	Type	Weight Percent of Material by Mesh Sizes				
		0-12	12-60	60-100	100-200	>200
Floor	Blasted Media	0.13	94.0	5.6	0.27	0
Media Return	Recycled	0.13	95.7	4.2	0	0
Cyclone	Rejected	0	60.7	26.8	8.7	3.8
Screen Under	Rejected	0	0.1	44.7	49.4	5.8
Screen Over	Rejected	25.6	73.2	0.5	0.6	0.6
Baghouse	Rejected	0	17.7	20.3	44.2	17.8

Table 7. Particle Size Distribution of the Hill AFB Walk-in Booth

Location	Type	Weight Percent of Material by Mesh Sizes				
		0-12	12-60	60-100	100-200	>200
Test Series One						
Floor	Blasted Media	0.1	96.0	2.8	0.9	0.2
Media Return	Recycled	0.06	99.8	0.12	0	0
Classifier	Rejected	0	38.4	7.2	16.7	37.7
Screen Under	Rejected	0	39.3	46.6	11.2	2.9
Screen Over and Under	Rejected	0.1	28.1	42.1	23.4	6.2
Baghouse	Rejected	0	76.6	8.8	8.8	5.9
Test Series Two						
Floor	Blasted Media	0.1	94.5	3.7	1.6	0.4
Media Return	Recycled	0	99.7	0.2	0.02	0
Classifier	Rejected	0	17.5	8.4	39.6	34.4
Screen Over and Under	Rejected	0.1	28.4	39.1	23.2	9.2
Magnetic Sep.	Rejected	0	90.4	4.1	4.0	1.5

Table 8. Particle Size Distribution of the Hill AFB F-4 Aircraft Blast Room

Location	Type	Weight Percent of Material by Mesh Sizes				
		0-12	12-60	60-100	100-200	>200
Floor	Blasted Media	0.5	81.4	13.6	3.6	1.0
Wing	Blasted Media	0	94.0	5.7	0.3	0
Media Return	Recycled	0.1	94.9	4.7	0.4	0.04
Ventilation Baghouse	Rejected	0	10.5	33.9	45.3	10.3
Media Baghouse	Rejected	0	49.2	30.7	14.2	5.9

particle breakdown caused by the blasting process. The performance of the recycling equipment at each PMB site is discussed in greater detail in sections 3, 4, and 5.

Recycling equipment at the NAVAVNDEPOT Pensacola walk-in booth returns about 4 percent undersize material to the blast vessel. Dust in the usable media can increase dust levels in the booth during operation. The cyclone fine fraction contained nearly 61 percent reusable particles in the 12 to 60 mesh range. This is a notable loss accounting for much of the 12 to 60 mesh particles found in the baghouse waste sample. Usable media is also being rejected from the vibrating screen, but since the media flow rate at the screen reject is very low, actual media losses are minimal.

The air clasifier at the Hill AFB walk-in booth effectively removes dust and fines from the media return. The samples also reveal a high percentage of usable media (12 to 60 mesh in size) present in the supposedly fine material rejected from the air classifier and the vibrating screen. The baghouse waste also contains 12 to 60 mesh material. Although the air classifier rejects an excessive amount of properly sized material, it can not account for the 76.6 percent of 12 to 60 mesh media found in the baghouse sample. Much of the properly sized material found in the baghouse has been traced to media introduced into the ventilation system during blast operations and floor clean-up. Media losses from the vibrating screen are relatively minor.

6.3 Specific Gravity Determinations

The specific gravity for various media samples is shown in table 9. The specific gravity of new media was also determined for reference. The samples at each location have been ranked in order of increasing specific gravity to show the general trend. The range of values is relatively narrow, however, specific gravity tends to increase as the metallic contamination in the sample increases.

Table 9. Specific Gravities of Dust and Media Samples

Test Site	Location	Specific Gravity
NAVAVNDEPOT Pensacol Walk-in Booth	New Media*	1.15-1.18
	Media Return	1.24-1.29
	Floor	1.26
	Diverter	1.26
	Screen Oversize	1.27
	Screen Undersize	1.27
	Cyclone Reject	1.42
	Baghouse	1.57
Hill AFB Walk-in Booth Test Series One	New Media**	1.38-1.39
	Cyclone Reject	1.38
	Media Return	1.44-1.61
	Screen Over/Undersize	1.45
	Screen Undersize	1.45
	Floor	1.45
	Baghouse	1.48
Hill AFB Walk-in Booth Test Series Two	New Media	1.38-1.39
	Baghouse	1.38-1.45
	Cyclone Reject	1.43
	Screen Undersize	1.43
	Recycled	1.44
	Floor	1.46
	Screen Over/Undersize	1.50
	Magnetic Separator	2.41
Hill AFB F-4 Aircraft Room	New Media	1.38-1.39
	Media Return	1.41
	Floor	1.41-1.43
	Media Baghouse	1.43
	Ventilation Baghouse	1.46
	Wing	1.48

NOTES:

* New media used and collected at NAVAVNDEPOT Pensacola was manufactured by U.S. Technology, Polyextra grade.

** New media used and collected at Hill AFB was manufactured by U.S. Technology, Polyplus grade.

6.4 Silica Concentration Analyses

Hard particle contaminants in the recycled media may be a factor in mechanical damage experienced by the substrate under certain conditions.[3]

Hard particles are identified as silica (sand) and metal chips. Samples taken at each PMB site were analyzed to determine silica concentrations. The analysis was performed using an ashed portion of the sample subjected to an arc/spark spectrograph. The instrument used was an Applied Research Labs 1.5 Meter Grating Spectrograph. Table 10 presents the results of the silica analysis. The table is arranged in order of increasing silica content. The percent of material remaining after ignition is also reported and typically contains various nonflammable constituents.

Silica (as various silicates) is a component used in pigments. The spectrographic method used to determine the silica concentration could not distinguish between silica present in pigments and hard sand particles, therefore, it is erroneous to assume that all of the silica measured by this method in the recycled media samples is capable of causing substrate damage.

Certain trends are evident from the data. In all cases the lowest silica concentrations are found in the cleaned recycled media samples, indicating that the media recycle process is effective in silica removal. Silica concentration increases as the concentration of small sized particles increases. (See paragraph 6.2 for a discussion on paticle size distributions.) Silica is possibly present as a very small particle that is captured by the ventilation system or carried into the recycling system on larger particles. The fine silica is then washed from the larger particles by the action of the cyclone separator and/or the vibrating screen. The air classifier reject samples collected at the Hill AFB walk-in booth contain high silica concentrations. Particle size distributions indicate that this classifier rejects the majority of small particles.

The cyclone reject at the NAVAVNDEPOT, Pensacola does not contain as much silica as the cyclone reject at Hill AFB. The Pensacola cyclone, however, is rejecting a much higher percentage of large sized material. Further evidence of silica concentrating in the small size ranges is its very high concentration (16,000 mg/kg) in the ventilation baghouse at the F-4 blast room. This baghouse contained a majority of very fine material. There is little correlation between silica concentration and the specific gravity of the sample. Specific gravity is not recommended as a contamination control parameter. As discussed in paragraph 6.3, specific gravity tends to increase as the metallic contamination in the sample increases.

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3. Battelle. Plastic Bead Blast Materials Characterization Study Summary Report for Period October 1986 to March 1987. Prepared for Air Force Corrosion Program, Robins Air Force Base. March 1987.

Table 10. Silica Content of Dust and Media Samples

Test Site	Sample Location	Silica Content (milligrams/ (kilogram)	Percent Sample Left on Ignition
NAVAVNDEPOT Pensacola	Media Return	1500	1.7
	Cyclone Reject	1600	1.2
	Floor	1900	1.6
	Baghouse	3500	2.8
	Screen Undersize	7600	5.1
	Screen Oversize	8800	6.0
Hill AFB Walk-in Series 1	Media Return	1400	2.8
	Floor	2200	2.9
	Baghouse	4300	2.5
	Screen Undersize	4400	4.2
	Cyclone Reject	5800	4.3
	Screen Over/Undersize	6200	4.5
Hill AFB Walk-in Series 2	Media Return	680	2.8
	Floor	780	2.9
	Magnetic Separator	4000	47.8(31% iron)
	Screen Over/Undersize	9500	6.0
	Cyclone Reject	9900	5.3
Hill AFB F-4 Blast Room	F-4 Wing*	2000	3.0
	Media Return	2600	3.1
	Floor	5300	3.5
	Media Baghouse	7400	5.0
	Ventilation Baghouse	16000	10.1

NOTES:

* Special Sample location - not part of recycle system.

6.5 Total Metal Concentration Analyses

Used media and dust collected in a baghouse are disposed of as hazardous waste because of the high concentration of metals in the material. The disposal cost of this material can add significantly to the operating costs of a blasting operation. Reducing the amount of hazardous waste generated will provide a more economical and environmentally sound blasting operation.

Samples of new media, used media, and dust collected at the various sampling points were analyzed for total metals content with specific tests for cadmium, chromium, lead, nickel, iron, zinc, titanium, aluminum, and barium.[4].

6.5.1 Analysis of New Media

The results of this analysis for metal concentrations in new plastic media were unexpected. High levels of lead were found in the Polyextra media sampled at NAVAVNDEPOT, Pensacola. The Polyplus media sampled at Hill AFB contained high levels of barium, aluminum, and zinc; but minimal lead. The exact concentrations are shown in table 11. The limit of detection has been reached or exceeded for data preceded by the less than symbol (<).

Table 11. Total Metal Concentration in Samples of New Media

Site	Type	Size (mesh)	Metal Concentration (parts per million (ppm))								
			Cr	Zn	Cd	Pb	Ni	Fe	Ti	Al	Ba
Hill AFB	PP**	12-16	2.7	1870*	3.4	<9.4	<1.4	86.7	12.4	118*	4670*
Hill AFB	PP**	30-40	1.8	7920*	1.1	<2.6	<1.4	22.8	117	482*	7880*
NAVAVN-DEPOT Pensacola	PE***	12-16	<0.8	<3.1	<0.9	2960*	<1.4	<1.0	12.5	12.3	1.3

NOTES:

* Significant Concentration.

** U.S. Technology Polyplus grade.

*** U.S. Technology Polyextra grade.

4. Environmental Protection Agency. Test Methods for Evaluating Solid Waste Physical/Chemical Methods, SW-846, Second Edition, 1982.

The classification of hazardous waste is promulgated by federal, state, and local regulations. Depending on the location of the PMB facility, and the governing hazardous waste regulations, it may be possible to reclassify waste as nonhazardous if the concentration of particular metals are reduced. The high initial concentration of metals in the new plastic media may become a factor in attempting to delist this waste. Media purchase specifications may require that a maximum limit be placed on metal concentration. The chemical analyses of used media in tables 12 through 14 indicate that new media is a major contributor of metals contamination in samples of solid waste generated by the blasting operation.

6.5.2 Analysis of Used Media

Results of the total metal concentration analyses for samples of recycled media, dust, and media rejected from the recycling systems are shown in tables 12 through 14. Several samples of dust and media rejected from the various baghouses and cyclone separators were analyzed for total metals in up to three size ranges. New media has also been analyzed; the information is included in the tables to provide control group data.

6.6 Leachable Metal Concentrations in Dust and Rejected Media

Baghouse dust samples and samples of media rejected from the various systems were collected, sieved into various size ranges, and subjected to EP toxicity tests to determine leachable metal concentrations.[5] Table 15 presents leachable metal concentrations in baghouse waste dust in units, milligrams per liter (mg/l) consistent with EP Toxicity protocol. Levels of chromium, cadmium, and lead, in excess of the maximum allowable concentration (MAC), characterize this material as hazardous waste. The MAC for chromium was exceeded at each site. Levels were especially high at the F-4 blast room. The MAC for cadmium was exceeded at each site, and chromium concentrations were very high in the small size screen reject at NAVAVNDEPOT, Pensacola. The MAC for lead was exceeded at all sites in the smaller size ranges (passing through a 100 mesh screen). New Polyextra media exceeds the EP toxicity limit for lead. The high leachable lead concentration in new Polyextra media corresponds with high total lead levels found in samples of this media (see paragraph 6.3.1).

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5. 40 Code of Federal Regulations Chapter I 261.24 - Characteristics of EP Toxicity. Protection of Environment, July 1 1986.

Table 12. Total Metal Concentration in Collected Samples NAVAVNDEPOT Pensacola Walk-in Booth

Location	Particle Size (mesh)	Percent of Sample	Concentration (ppm)								
			Cr	Zn	Cd	Pb	Ni	Fe	Ti	A	Ba
Unused PE	12 - 16	NA	<0.8	<3.1	<0.9	2960	<1.4	<1.0	12.5	12.3	1.3
Floor	Composite*	NA	172	376	3.5	442	<1.4	67.7	112	227	289
Media Return	Composite	NA	368	389	3.0	876	38	741	574	345	281
Cyclone Reject	Composite	NA	339	1010	13.9	255	<1.4	698	46.8	418	118
Screen Undersize	Composite	NA	1260	804	204	165	9.7	2080	810	1640	291
Screen Oversize**	Composite	NA	3000	953	133	701	2.0	2190	1590	10400	964
Baghouse	Composite	NA	1580	2150	592	501	<1.4	848	39.9	2130	16.9
Baghouse	<200***	59.8	627	1050	80.2	348	2.7	<1.0	81	591	154
Baghouse	>200	40.2	3260	3090	1530	755	37.7	1800	28.9	3940	248

NOTES:

* Composite sample was analyzed with no size segregation.

** Material consisted largely of paint chips.

*** <200 mesh refers to particles retained on a 200 mesh screen (larger particles).

>200 mesh refers to particles passing through a 200 mesh screen (smaller particles).

Table 13. Total Metal Concentration in Collected Samples
Hill AFB Walk-in Booth

Location	Particle Size (mesh)	Percent of Sample	Concentration (ppm)								
			Cr	Zn	Cd	Pb	Ni	Fe	Ti	Al	Ba
Unused PP	30 - 40	NA	1.8	7920	1.1	<2.6	<1.4	22.8	117	482	7880
Test Series One											
Floor	Composite*	NA	31.3	3610	25	28.6	7.1	724	100	195	10100
Media Return	Composite	NA	10.6	3700	19.8	22.3	<1.4	559	147	158	9780
Cyclone Reject	Composite	NA	811	2940	144	713	<1.4	1853	102	2443	6330
Screen Undersize	Composite	NA	506	3880	586	406	4.0	2440	86.2	503	9060
Screen Over/ Undersize	Composite	NA	445	3430	34.3	455	75.2	1730	145	486	8560
Baghouse	Composite	NA	613	3920	78.7	241	97.3	2080	94.6	907	7760
	<200**	92.2	405	3610	35.2	262	1.4	941	120	640	180
	>200	7.8	720	3480	648	671	21.9	461	88.6	6160	7400

NOTES:

* Composite sample was analyzed with no size segregation.

** <200 mesh refers to particles retained on a 200 mesh screen (larger particles).

>200 mesh refers to particles passing through a 200 mesh screen (smaller particles).

Table 13. Total Metal Concentration in Collected Samples Hill AFB Walk-in Booth ... (Cont)

Location	Particle Size (mesh)	Percent of Sample	Concentration (ppm)								
			Cr	Zn	Cd	Pb	Ni	Fe	Ti	Al	Ba
Test Series Two											
Floor	Composite	NA	31.9	1730	29	28.6	<1.4	601	118	219	4590
Media Return	Composite	NA	66.8	3810	22	7.9	21	987	145	161	9820
Cyclone Reject	Composite	NA	1430	3120	147	976	16.5	405	83.4	2770	6530
	<100	23.1	621	2770	26.5	428	<1.4	903	279	319	7490
	100-200	37.7	1600	2710	52.4	1230	5.1	1440	159	2300	6150
	>200	39.2	1360	2530	371	1420	25.1	2830	143	3660	4790
Screen Over/ Undersize	Composite	NA	462	3610	156	588	3.0	1720	180	613	9520
Magnetic Separator	Composite	NA	1420	3510	564	2050	2880	20000	188	424	2570
Baghouse	<100	94.2	452	3290	114	160	<1.4	752	116	696	6100
	100-200	4.5	1920	3980	532	504	12.3	2960	129	4380	7250
	>200	1.3	1690	3490	1110	490	12.0	3310	124	4100	5360

Table 14. Total Metal Concentration in Collected Samples
Hill AFB F-4 Aircraft Blast Room

Location	Particle Size (mesh)	Percent of Sample	Concentration (ppm)								
			Cr	Zn	Cd	Pb	Ni	Fe	Ti	Al	Ba
Floor	Composite*	NA	304	3000	257	285	<1.4	1350	152	559	8710
Wing	Composite	NA	248	3220	14.5	231	<1.4	1320	182	235	8780
Media Return	Composite	NA	145	3390	12.8	90.5	21.2	1490	186	201	9380
Ventilation Baghouse	Composite	NA	2540	2410	528	1970	4.0	4730	151	4340	5980
Media Baghouse	Composite	NA	1250	3140	63.1	853	<1.4	2830	236	775	7490

NOTES:

* Composite sample was analyzed with no size segregation.

Table 15. Leachable Metal Concentration in Collected Samples

			Metal Concentration (mg/l)									
			Cr	Zn	Cd	Pb	Ni	Fe	Ti	Al	Ba	Total
Maximum Allowable Concentration (mg/l)			5.0	----	1.0	5.0	----	----	----	----	100.0	
Site	Location	Size (mesh)										
	New Polyextra	12-16	<0.1	--	<0.05	10.3	--	--	--	--	<0.1	--
Pensacola	Baghouse	<200*	32.25	45.55	1.24	15.95	<0.07	<0.05	0.115	3.19	8.7	107
Pensacola	Baghouse	>200	20.35	57.5	14.6	27.15	0.08	<0.05	0.125	15.9	20.9	157
	New Polyplus	30-40	<0.1	--	<0.05	<0.8	--	--	--	--	<0.8	--
Hill WI**	Baghouse	<200	10.55	54.0	2.945	3.17	<0.07	<0.05	<0.25	<0.145	0.725	72
Hill WI	Baghouse	>200	72.0	57.0	14.65	16.5	0.215	<0.05	<0.25	6.75	2.20	170
Hill WI	Screen Over/ Undersize	<100	19.55	520.0	3.67	3.8	<0.07	<0.05	<0.25	<0.145	1.19	549
		100-200	22.35	570.0	15.5	5.6	0.275	<0.05	<0.25	2.455	0.49	639
		>200	21.7	560.0	476.0	83.5	1.625	1.11	0.11	19.3	2.465	1166
Hill F-4	Ventilation Baghouse	<100	111.5	414.0	124.0	39.3	0.165	<0.05	0.04	10.0	3.05	702
		100-200	33.95	69.0	20.6	4.825	<0.07	<0.05	<0.25	3.745	12.6	145
		>200***	----	----	----	----	----	----	----	----	----	----
Hill F-4	Media Baghouse	<100	9.95	489.0	1.89	4.565	<0.07	<0.05	<0.25	1.07	1.235	508
		100-200	119.5	464.5	7.9	6.2	<0.07	<0.05	<0.25	4.735	2.26	605
		>200	148.0	386.5	7.7	39.75	0.135	<0.05	0.11	9.75	1.885	594

* <200 mesh refers to particles retained on a 200 mesh screen (larger particles).

>200 mesh refers to particles passing through a 200 mesh screen (smaller particles).

** Hill WI refers to the Hill AFB walk-in blast booth.

*** Insufficient sample for analysis.

7.0 PROCEDURE FOR ESTIMATING THE VALUE OF REUSABLE MEDIA LOSSES

The value of increasing the percentage of reusable media recovered from plastic media recycle equipment is calculated using two factors:

1. The amount of media used in the blasting operation.

2. The system recovery percentage.

The amount of media used in the blasting operation can be defined as the amount of media passing through the blasting nozzle. The system recovery percentage has been previously defined as the overall amount of reusable media recovered after one pass through the equipment. The cost of using new media is taken from an NCEL Contract Report.[6]

7.1 Economic Calculation Example

The following example lists the data necessary to calculate potential economic benefits to be realized by increasing the recovery percentage of a plastic media recycling facility.

Assumptions:

Amount of media blasted through nozzle:	600 pounds per hour
Hours per day media is passing through nozzle:	10 hours
Number of days per year that blasting facility is operated:	250 days
Cost per pound of plastic media:	$2.00
Initial recovery percentage with undersized cyclone:	81 percent
Estimated recovery percentage with adequately sized cyclone:	93 percent

1. Calculate the amount of media used by facility annually.

Amount of media used by facility annually is the product of the rate of media used per nozzle hour and the hours per year that the nozzles are operated.

$$\text{Annual Media Usage} = \frac{600\ \text{pounds}}{\text{nozzle hour}} \times \frac{10\ \text{nozzle hours}}{\text{day}} \times \frac{250\ \text{days}}{\text{year}} = \frac{1{,}500{,}000\ \text{pounds}}{\text{year}}$$

6. Naval Civil Engineering Laboratory. Contract Report CR 87.001: Economic Analysis for Recycling Plastic Media: Final Report. Camarillo, CA, Engineering Management Concepts, February 1987.

2. Calculate percentage difference between reusable media recovery factors.

The amount of reusable media lost due to inadequate media recycling equipment can be calculated by considering the media recovery factors. By definition, the media recovery factor is the percentage of reusable media recovered from an initial amount of media used during blasting.

Estimated recovery percentage with adequately sized cyclone:		93 percent
Initial recovery percentage with undersized cyclone:		81 percent
	Difference	12 percent

3. Apply percentage difference to the annual amount of media used to calculate estimated savings.

$$\text{Annual Estimated Savings} = \frac{1{,}500{,}000 \text{ pounds}}{\text{year}} \times \frac{\$2.00}{\text{pound}} \times 12 \text{ percent} = \$360{,}000$$

7.2 Discussion of Economic Calculations

The significant savings of over $300,000 annually in the above example was estimated using reasonable assumptions of media flow rates and increased recovery percentages. Note that even a 1 percent improvement in the recycling percentage, due to a change in vibrating screen operation or other minor adjustments, would save an estimated $30,000 annually.

Another benefit from increased media recovery is the reduced quantity of hazardous waste. This amount is small in comparison; adding only 6 percent to the savings if hazardous waste disposal is costing $200 per ton or $0.10 per pound. The more significant savings is in the $2.00 per pound cost of replacement media.

8.0 RECOMMENDATIONS

The following recommendations are based on the result of tests and observations performed at the three PMB sites. The recommendations are broad in scope and are factors to consider in the design of new PMB facilities or in the retrofit of existing equipment.

1. **Floor Recovery Systems.** Manual media recovery is appropriate for small enclosures with limited production requirements. A cost effective alternative to manual recovery is the portable vacuum pan. Although not evaluated in this analysis, the portable recovery pan appears to minimize some of the problems experienced with manual recovery.

The decision to use partial or full recovery floor systems must be based on the size of the enclosure, the types of parts or aircraft being blasted, desired production rates, existing facilities at the blast location, and the cost of the systems. Full floor recovery systems are recommended for walk-in booths that must maintain a high production rate. Partial recovery systems are applicable in larger PMB enclosures or when retrofitting an aircraft hangar for PMB. Partial recovery floors are also preferred when floor loading is expected to be great. It is suggested that the configuration of the workpiece be considered when a partial recovery floor is installed. Recovery troughs or pits should be located where the highest concentration of blasted material is expected to fall. Recovery troughs or pits should not be placed near ventilation exhausts.

Pneumatic and mechanical recovery mechanisms are applicable to both partial and full floor recovery systems. Further evaluation of these recovery mechanisms is suggested. Pneumatic full floor recovery sytems should be sequenced as described in paragraph 3.2. Use of a Programmable Logic Controller is suggested to control the sequencing. The air flow through the floor hoppers should be as low as possible to prevent media carryout at the cyclone, but must be sufficient to prevent plugging. The design of the small floor hopper outlets should minimize plugging. The cone of material formed in the pneumatic ductwork as it is released through the hopper, should not impede air flow through the duct.

2. **Cyclone Separators.** A cyclone separator is necessary to remove fine dust that adheres to the media. The cyclone, however, is responsible for a large percentage of recoverable media losses in the system. There is a strong economic incentive to properly design and size the cyclone. Most cyclones used in the PMB application are undersized. Newer, second generation PMB equipment that incorporate a type of air knife arrangement appears to efficiently remove fine particles from the material stream and minimize the carryout of properly sized material. Further studies are recommended to optimize cyclone design.

3. **Screens.** At this time, a vibrating screen is recommended to size the material as it exits the cyclone separator. It is suggested that the size classification be accomplished after the mass separation is completed in the cyclone. Any particle less than 60 mesh in size that is not removed by the cyclone will pass through both screens and be collected for disposal. The top

screen (overize screen) is necessary to capture and dispose of particles larger than 12 mesh in size. If the cyclone incorporates an air knife arrangement, then the vibrating screen may not be necessary. Undersize material is almost completely removed from the material stream before it reaches the screen. An oversize screen is still required to capture particles larger than 12 mesh in size. The screen may be stationary; requiring manual cleaning at specific intervals, or if neeeded in high volume applications, the screen should incorporate means for automatic cleaning.

4. **Rotary Valve.** Rotary valves are high maintenance items. Consideration should be given to utilizing a system design that eliminates the need for a rotary valve such as the system at the NAVAVNDEPOT Pensacola walk-in booth.

5. **Magnetic Separator.** A magnetic separator is required to remove ferrous particles from the recycled media. It is recommended that the magnetic separator be of the automatic self-cleaning type.

6. **Ventilation System.** Ventilation system design for PMB enclosures has not been specifically addressed by this report. The ventilation system, however, can cause unnecessary media losses if improperly designed. Enclosure ventilation should be a separate system that is not tied in any way to the media floor recovery system. Ventilation exhausts should not be located near floor recovery pits or trenches. Ventilation exhausts should be covered or baffled to prevent media from entering the ventilation system. Exhaust plenums should incorporate a gravity settling chamber to provide media particles time to settle out the the ventilation air stream. Dust filters should be of the automatic cleaning type. Both cartridges and fabric filters are acceptable filtering mediums. Cartridge filter units may be the more economical choice.

7. **Media Washing Equipment.** The use of media washing equipment should be avoided if possible by practicing good housekeeping procedures to minimize hard particle contamination in the media. If an installation can not maintain hard particle contamination at a reasonable level, a media washing system may be indicated. The system should not utilize hazardous chemicals as the flotation liquid. More research to develop effective and safe media washing equipment is recommended.

8. **Waste Disposal.** Dust and material collected from the PMB operation must be disposed of as hazardous waste. New media should not contain high levels of total and leachable lead.

APPENDIX A

NAVAL AVIATION DEPOT PENSACOLA, FLORIDA
WALK-IN PLASTIC MEDIA BLAST BOOTH
VENTILATION AIR FLOW MEASUREMENT AND CALCULATIONS

Figure A-1 shows Pitot tube traverse points near the baghouse inlet which handles all booth flow including the floor pick-up system component. The duct measures 36 inches by 12 inches. Figures in the squares show actual velocity pressure readings in inches of water column (in. H_2O). The top series of numbers represent the first series of measurements; the bottom series represent the second series of measurements. All measurements and subsequent calculations to obtain air velocities are in accordance with the American Conference of Governmental Industrial Hygienists (ACGIH) Manual of Industrial Ventilation[1]. Duct air temperature was 70 degrees Fahrenheit (^{o}F). No correction was necessary for air temperature or pressure since the equipment is located at sea level.

The velocity (V) was calculated according to the following formula:

$$V = 4005\sqrt{VP}$$

where: VP - velocity pressure (in. H_2O)

	A	B	C	D	E	F	G	H
1	0.27 + 0.28	0.275 + 0.27	0.27 + 0.26	0.29 + 0.29	0.28 + 0.30	0.24 + 0.25	0.17 + 0.19	0.17 + 0.15
2	+	0.275 + 0.27	0.23 + 0.21	0.245 + 0.215	0.24 + 0.24	0.20 + 0.22	0.18 + 0.18	0.1 + 0.1
3	+	0.28 + 0.22	0.245 + 0.23	0.245 + 0.23	0.25 + 0.24	0.235 + 0.23	0.20 + 0.20	0.17 + 0.1
4	0.23 + 0.21	0.24 + 0.23	0.22 + 0.22	0.21 + 0.22	0.23 + 0.225	0.24 + 0.23	0.24 + 0.23	0.22 + 0.21

FIGURE A-1. PITOT TUBE TRAVERSE POINTS IN MAIN BOOTH EXHAUST DUCT

Air flow was blocked in locations A2 and A3 by a 6 inch by 6 inch partition.

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[1] American Conference of Governmental Industrial Hygienists. Industrial Ventilation - A Manual of Recommended Practice. Ann Arbor, MI, Edwards Brothers, Inc., 1980.

Table A-1 shows the measured VP's and calculated Vs obtained from the main booth exhaust duct.

Table A-1. Main Booth Exhaust Duct Measurements

Test Series One			Test Series Two		
Location	VP (in. H_2O)	V (fpm)	Location	VP (in. H_2O)	V (fpm)
A1	.27	2081	A1	.28	2119
B1	.275	2100	B1	.27	2081
C1	.27	2081	C1	.26	2042
D1	.29	2157	D1	.29	2157
E1	.28	2119	E1	.30	2194
F1	.24	1962	F1	.25	2003
G1	.17	1651	G1	.19	1746
H1	.17	1651	H1	.15	1551
A2	----	----	A2	---	----
B2	.275	2100	B2	.27	2081
C2	.23	1921	C2	.21	1835
D2	.245	1983	D2	.215	1859
E2	.24	1962	E2	.24	1962
F2	.20	1791	F2	.22	1879
G2	.18	1699	G2	.18	1699
H2	.19	1746	H2	.19	1746
A3	----	----	A3	----	----
B3	.28	2119	B3	.22	1879
C3	.245	1982	C3	.23	1921
D3	.245	1983	D3	.23	1921
E3	.25	2003	E3	.24	1962
F3	.235	1941	F3	.23	1921
G3	.20	1791	G3	.20	1791
H3	.17	1651	H3	.19	1746
A4	.23	1921	A4	.21	1835
B4	.24	1962	B4	.23	1921
C4	.22	1879	C4	.22	1879
D4	.21	1835	D4	.22	1879
E4	.23	1921	E4	.225	1900
F4	.24	1962	F4	.23	1921
G4	.24	1962	G4	.23	1921
H4	22	1879	H4	.21	1835
	Total:	57795		Total:	57184
	Average:	1925.5		Average:	1906.1

Average velocity through the duct is 1916 fpm.

Duct area:
(Duct area) - (Obstructed area) = Area
(3 ft)(1.5 ft) - (.5 ft)(.5ft) = 4.25 sq ft

Volume through duct:
$Q = AV = (4.25\ ft^2)(1916\ ft/min) = 8143\ cfm$

Air flow through booth:
Booth area = 10 ft * 12 ft = 120 sq ft

$$\frac{8143\ \text{cfm}}{120\ \text{sq ft}} = 67.9\ \text{fpm}$$

Part of this flow is downward due to the floor suction. A calculation of the floor air flow rate follows:

Figure A-2 shows the Pitot traverse points in the duct. The duct size is 8 inches by 8 inches. Figures in the squares show actual velocity pressure readings in in. H_2O. The top series of numbers represent the first series of measurements; the bottom series represent the second series of measurements. Table A-2 provides velocity pressure measurements and calculated air velocities.

	A	B	C
1	.18 + .19	.18 + .22	.19 + .20
2	.23 + .23	.23 + .23	.225 + .23
3	.21 + .20	.23 + .20	.23 + .23

FIGURE A-2. PITOT TUBE MEASUREMENT LOCATIONS IN THE FLOOR DUCT.

Table A-2. Floor Exhaust Manifold Measurements

Test Series One			Test Series Two		
Location	VP (in. H_2O)	V (fpm)	Location	VP (in. H_2O)	V (fpm)
A1	.18	1699	A1	.19	1746
B1	.18	1699	B1	.22	1879
C1	.19	1746	C1	.20	1791
A2	.23	1921	A2	.23	1921
B2	.23	1921	B2	.23	1921
C2	.225	1900	C2	.23	1291
A3	.21	1835	A3	.20	1791
B3	.23	1921	B3	.20	1791
C3	.23	1921	C3	.23	1921
	V Total:	16563		V Total:	16682
	V Average:	1840.3		V Average:	1853.5

Average air flow through the floor is 1846.9 fpm

Duct area:
(8 in)(8 in) = 64 sq in = 0.444 sq ft

Volume through duct:
Q = AV = (.444 sq ft)(1846.9 ft/min) = 820 cfm

The horizontal component of air flow through booth is equal to the total booth air flow minus the air flow through the floor:

8114 cfm - 820 cfm = 7294cfm

Total horizontal air flow:

$$\frac{7294 \text{ cfm}}{120 \text{ sq ft}} = 61.0 \text{ fpm}$$

APPENDIX B

HILL AIR FORCE BASE, OGDEN, UTAH
PLASTIC MEDIA BLASTING WALK-IN BOOTH
AIR FLOW MEASUREMENTS AND CALCULATIONS

1. Main Booth Exhaust Duct

Figure B-1 shows Pitot tube traverse points in the main booth exhaust duct. The duct measured 24 inches in diameter. Duct air temperature was 66°F, and the barometric pressure was 26.00 inches of mercury (in.Hg). Velocity pressure (VP) was measured in inches of water column (in. H_2O). The velocity (V) was calculated and corrected for variations in temperature and pressure according to the following formulas referenced from the ACGIH Industrial Ventilation[1]:

$$V = 1096 \sqrt{VP/0.075d}$$

where d = density factor = (correction for temperature) *(correction for temperature)

$$d = (530/460 + 66) * (26.00/29.92) = 0.88$$

Table B-1 shows the measured VPs and calculated Vs obtained from the main booth exhaust duct.

Table B-1. Main Booth Exhaust Duct Measurements

	Side (X)		Side (Y)	
Distance from wall (inches)	Measured VP (in. H_2O)	Corrected V (fpm)	Measured VP (in. H_2O)	Corrected V (fpm)
5/8	0.48	2956	0.31	2375
2	0.55	3164	0.49	2986
3 1/2	0.62	3359	0.53	3106
5 1/2	0.63	3386	0.54	3135
8 1/4	0.62	3359	0.57	3221
15 3/4	0.56	3193	0.61	3332
18 1/2	0.55	3164	0.58	3249
20 1/2	0.54	3135	0.53	3106
22	0.52	3076	0.50	3017
23 3/8	0.42	2765	0.42	2765

Average velocity (V_{AVG}) = 3092 fpm

1. American Conference of Governmental Industrial Hygienists. Industrial Ventilation - A Manual of Recommended Practice. Ann Arbor, MI, Edwards Brothers, Inc., 1980.

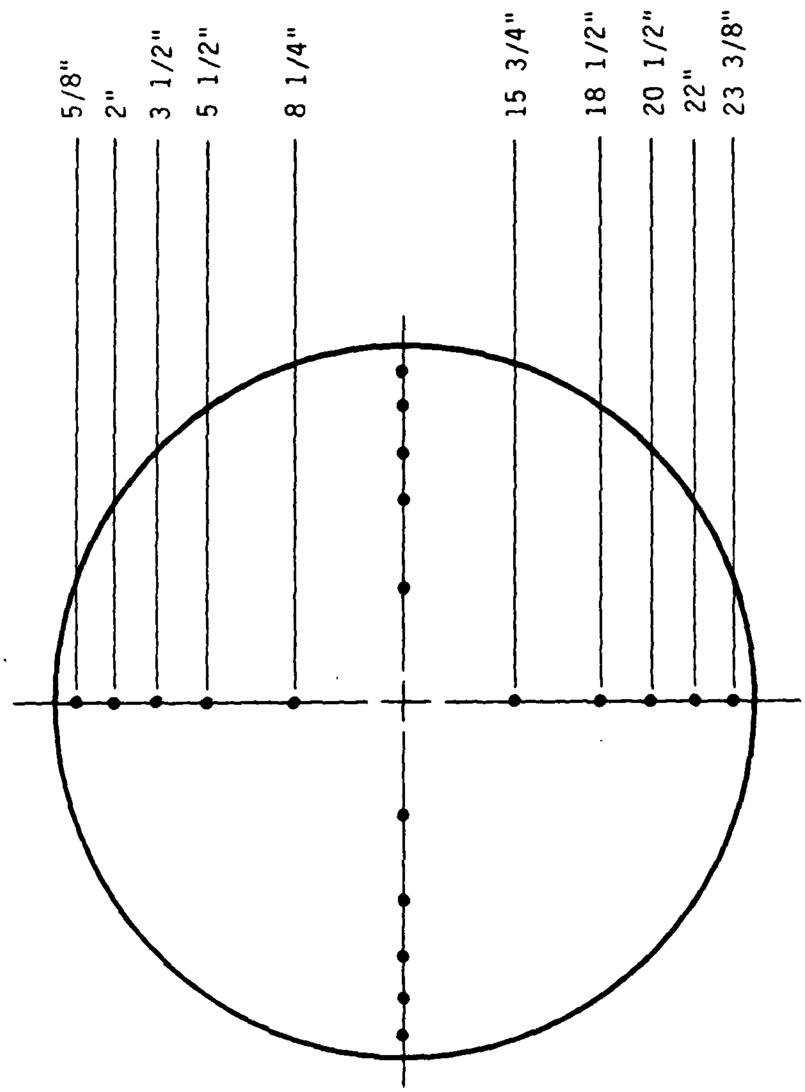

FIGURE B-1. PITOT TUBE TRAVERSE LOCATIONS IN A 24-INCH DIAMETER DUCT.

Volume through duct:
$Q = AV = (3.142 \text{ sq ft}) * (3092 \text{ ft/min}) = 9715 \text{ cfm}$

Air flow through booth:
Booth dimensions = 15 ft (w) * 9.9 ft (h) * 31.2 ft (l)
Booth cross-sectional area = 149 sq ft
Booth volume = 4636 cu ft

$$\frac{9715 \text{ cu ft/min}}{149 \text{ sq ft}} = 65.2 \text{ fpm air through booth.}$$

2. Right Exhaust Duct

Figure B-2 shows Pitot tube traverse points in the right exhaust duct. The duct measured 17 inches in diameter. Duct air temperature was 66°F, and the barometric pressure was 26.00 in. Hg. The density factor was calculated to be 0.88. Table B-2 shows the measured VPs and calculated Vs in the right exhaust duct.

Table B-2. Right Exhaust Duct Measurements

	Side (X)		Top (Y)	
Distance from wall (inches)	Measured VP (in. H_2O)	Corrected V (fpm)	Measured VP (in. H_2O)	Corrected V (fpm)
1/2	0.05	954	0.31	2375
1 3/8	0.11	1415	0.31	2375
2 1/2	0.14	1596	0.33	2451
3 7/8	0.19	1860	0.32	2413
5 3/4	0.12	1478	0.31	2375
11 1/4	0.27	2217	0	
13 1/8	0.28	2257	0	
14 1/2	0.28	2257	0.01	427
15 5/8	0.27	2217	0.02	603
16 1/2	0.28	2257	0.07	1129

$V_{AVG} = 1633$ fpm

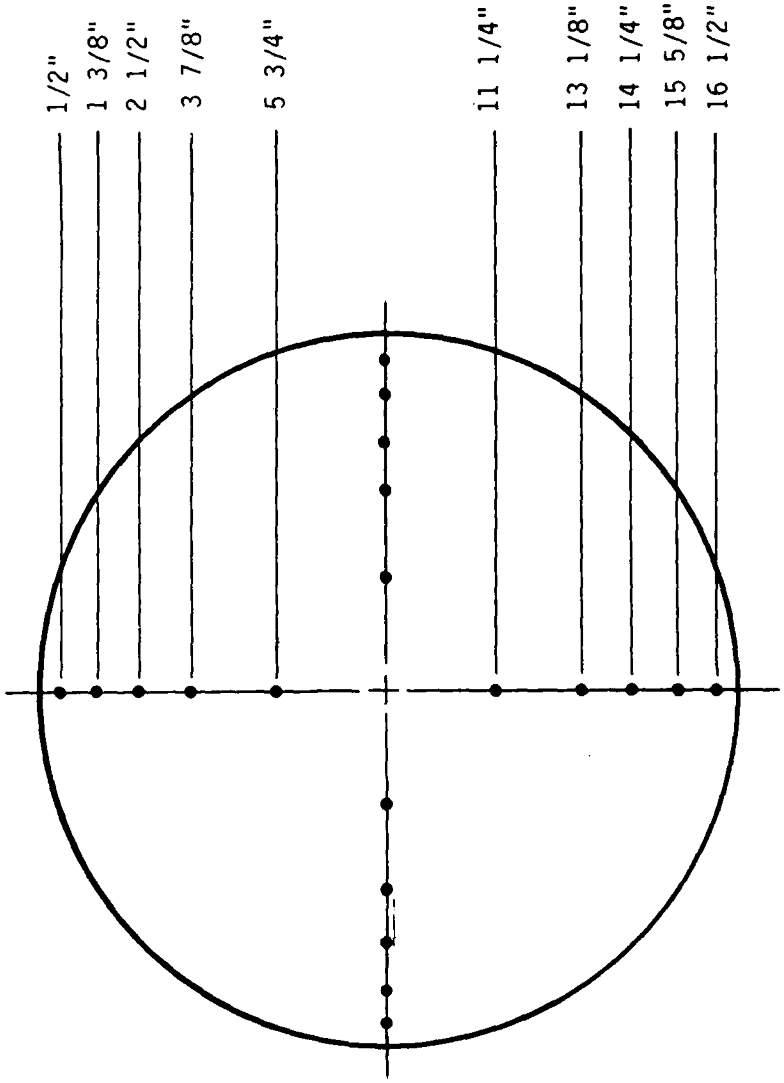

FIGURE B-2. PITOT TUBE TRAVERSE LOCATIONS IN A 17-INCH DIAMETER DUCT.

Volume through duct:
Q = AV = (1.576 sq ft)(1633 ft/min) = 2574 cfm (right exhaust)

Total exhaust - right exhaust = left exhaust
9715 cfm - 2574 cfm = 7141 cfm

Left exhausts 73.5 percent of booth air
Right exhausts 26.5 percent of booth air

3. Main Booth Supply Duct

Figure B-1 shows Pitot tube traverse points in a 24 inch duct. Duct air temperature was 73°F, and the barometric pressure was 26.00 in. Hg. The density factor was calculated to be 0.86. Table B-3 shows the measured VPs and calculated Vs in the main booth supply duct.

Table B-3. Main Booth Supply Duct Measurements

Distance from wall (inches)	Side X		Top (Y)	
	Measured VP (in. H_2O)	Corrected V (fpm)	Measured VP (in. H_2O)	Corrected V (fpm)
5/8	0.49	3021	0.35	2553
2	0.66	3506	0.49	3021
3 1/2	0.63	3425	0.49	3021
5 1/2	0.60	3343	0.47	2959
8 1/4	0.51	3082	0.41	2763
15 3/4	0.37	2625	0.41	2763
18 1/2	0.34	2516	0.41	2763
20 1/2	0.33	2479	0.41	2763
22	0.31	2402	0.37	2625
23 3/8	0.26	2200	0.34	2516

V_{AVG} = 2817 fpm

Volume through duct:

$Q = AV = (3.142 \text{ sq ft})(2817 \text{ ft/min}) = 8851 \text{ cfm}$

Air flow through booth:

$$\frac{8851 \text{ cu ft/min}}{149 \text{ sq ft}} = 59.4 \text{ fpm}$$

$$(\text{exhaust versus inlet}) = \frac{9715 - 8851}{9715} = 8.9 \text{ percent}$$

4. Average Airflow through booth

$$Q_{AVG} = \frac{9715 + 8851}{2} = 9283 \text{ cfm}$$

Average airflow through booth:

$$\frac{9283 \text{ cu ft/min}}{149 \text{ sq ft}} = 62.3 \text{ fpm}$$

Average air changes:

$$\frac{9283 \text{ cu ft/min}}{4636 \text{ cu ft}} = 2.0 \text{ air changes per minute}$$

PLASTIC MEDIA BLASTING RECYCLING EQUIPMENT TEST PLAN

Prepared for:

Naval Civil Engineering Laboratory

Port Hueneme, CA

Contract No. N00123-85-D-0901

Deliver Order No. J3-46

Enclosure 1

Engineering Management Concepts

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EXECUTIVE SUMMARY

Plastic media blasting as a method to remove paint offers time, quality, and waste handling advantages over chemical stripping. Economic comparisons are based largely on the costs of waste disposal and the amount of media regularly purchased to replace that fraction which is not recycled.

This test plan describes proposed step-by-step procedures to collect samples and information to aid in the evaluation of the equipment installed to recycle media for reuse. Samples will be collected for particle size distribution, metals contamination, specific gravity and other parameters.

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1.0 INTRODUCTION

The Naval Civil Engineering Laboratory (NCEL) has a requirement to evaluate the effectiveness of recycling equipment used in the Plastic Media Blasting (PMB) process. This study will be performed by Engineering Management Concepts (EMC) and will evaluate the effectiveness of cyclone separators, screens and magnetic separators in use at several military PMB operations. The study has been segmented into the following four phases:

1. Site visits to Hill Air Force Base (AFB) Ogden, Utah and the Naval Air Rework Facility (NARF) Pensacola, Florida to examine the PMB booths and recycling equipment which will be involved in subsequent testing and to establish logistics contacts and coordination points.

2. On-site evaluation of PMB recycling equipment at the F-4 aircraft blast booth and small parts walk-in booth at Hill AFB, and the small parts walk-in booth at NARF Pensacola.

3. Accumulation of test data and laboratory analysis of test samples.

4. Production of a final test report.

This test plan describes anticipated activities encompassed by phases two and three of the study.

1.1 Objectives

The objectives of this study are to test and evaluate the performance of PMB recycling equipment including percentage of usable media recycled, recycled media dust concentration, rejected media properties, reliability and maintainability, design parameters, and ease of operation. Samples of recycled media and rejected dust will be analyzed for size distribution, specific gravity, and specified contaminants.

1.2 Test Sites/Description of Process

The subjects of this study are as follows:

1. Small parts walk-in booth at NARF Pensacola. This booth is approximately 12 feet by 20 feet in size and is equipped with blasting equipment manufactured by Zero Manufacturing Company.

2. Small parts walk-in booth at Hill AFB. This booth is approximately 15 feet by 30 feet in size and is equipped with blasting equipment manufactured by CABER, Inc.

3. F-4 Aircraft blast booth at Hill AFB. This booth is approximately 45 feet wide by 74 feet long in size and was designed by Royce Mechanical Systems, Incorporated.

PMB is a paint removal process in which small, granular beads composed of a thermoset resin are forced at high velocities through a nozzle at a painted surface. The beads serve as an abrasive which dislodge surface coatings of paints and primers. One of the key benefits of using PMB in lieu of chemical stripping is lower operating cost factors. Savings are heavily dependent on the effectiveness of the equipment used to recycle the plastic media. The presence of usable media in rejected dust increases waste disposal costs and new media purchase costs, while the presence of dust in the recycled media decreases process efficiency. These concerns are alleviated through the use of an effective media recycling system.

1.3 Approach

Comparable testing approaches will be employed at the three PMB sites. Media and/or dust samples will be collected at key points in the recycling system. Most of these samples will be "grab type" samples. More elaborate methods will be used to obtain representative sample information when grab samples cannot be obtained directly without altering normal equipment operation. Samples will be analyzed to determine particle size distribution, specific gravity, silica content, and the concentration of specified metals. Additional information regarding actual equipment performance, reliability and maintainability will be obtained through observation and questioning of operational personnel. Analysis of data obtained during on-site testing will provide a basis for recommendations concerning equipment performance.

1.4 Test Equipment

The following equipment is anticipated for use at the test sites.

1. Sample collection zip-lock bags, labels and felt pen.
2. Vacuum cleaner bags.
3. Small hand tools, amprobe and strong magnets.
4. Linear measurement devices including calipers.
5. High intensity flash light and mirror.
6. Scale (0-100 pound) with 0.25 pound accuracy.
7. Sieve screens; 12, 60, 100, and 200 mesh.
8. Magnifying eyepieces with measurement scales.
9. Manometer, 0-24 inches of water and fittings.
10. Hand drill, extension, bits, taps and plugs.
11. Gloves and eye protection.

1.5 Proposed Test Schedule

It is anticipated that on-site testing will be performed at the Hill AFB sites from 31 March through 2 April 1987, and at the NARF Pensacola walk-in booth from 13 to 16 April 1987.

2.0 ON-SITE TEST PROCEDURES

During the initial site surveys of the three differently designed recycling systems, the test points to be evaluated were isolated. Sketches of each system were prepared, test points were numbered, and an explanation of the information to be acquired and proposed methodology was listed in the corresponding procedure subsection. For accurate assessment of process variables, it will be necessary to keep a record of operational breaks, personnel breaks, etc., during the test session. Operating conditions must ensure an adequate media supply throughout the sample collection period; new media must not be added to the systems during the test scenarios.

2.1 Walk-in Booth at NARF Pensacola, Florida

2.1.1 Background

The recycle equipment to be evaluated services a walk-in blast booth installed inside building 606. All major equipment was supplied by Zero Manufacturing Company, Inc. One equipment feature is a continuous media recovery system mounted beneath an open grate floor.

A schematic of the system is shown as Figure 1. Initial media separation is accomplished by a cyclone designed with an integral fan. The heavier fractions fall to the star valve where the material feeds into a vibrating screen separator. A diverter valve is mounted between the star valve and screen separator.

2.1.2 Sample Collection Procedure

The various samples to be collected (for each of the points indicated in this section) shall weigh not less than 2 pounds, and shall be collected no less than twice during test procedures. All collected samples shall be contained in ziplock bags, labeled, and stored pending later analytical procedures. As a minimum, samples will be subjected to particle size distribution and specific gravity determination.

A detailed explanation of the actual test procedure to be employed follows:

STEP 1 - Cyclone Feed Preparation (Point 11). Inspect the grate area for ease of removal. Select an area occupying actual blasting operations. Temporarily block selected funnel outlets. Cyclone feed (floor sample point 11) will be collected in the now inactive floor pickup spaces. Allow sample to accumulate. Samples will be analyzed for total metals content. (Point 11 sample collection procedure is outlined in Step 5.)

STEP 2 - Recycled Media (Point 17). Usable media from the vibrating screen is delivered to the feed nozzle via an interconnecting hose. Obtain a ladder for easy access. While floor sample at point 11 is accumulating, temporarily disconnect one end of this hose and collect a three pound sample. Sample will be analyzed for total metals content.

STEP 3 - Screen Dust Rejects (Point 15). Obtain samples of rejected media from the vibrating screen at the open hose which feeds directly into a collection drum. The sample will be analyzed for total metals content and for leachable metals when combined with the sample collected at point 13.

STEP 4 - Screen Oversize Rejects (Point 16). Obtain samples from collection drum.

STEP 5 - Dust Collector (Point 13). Collect a fresh sample of the settled dust at the bottom of the baghouse. The sample will be subjected to size determination and analyzed for leachable metals when combined with sample 15.

STEP 6 - Cyclone Reject Dust (Point 12). Partially remove the interconnecting hose to obtain a sample of rejected dust from the cyclone. A vacuum cleaner bag will be used to collect the dust. Repeat as required to obtain an adequate sample. Use this sample for total metals analysis only.

STEP 7 - Cyclone Feed Collection (Point 11). Obtain the initial sample by lifting the grate during a break in operation.

Repeat Steps 1 through 7 to obtain additional samples. Repetition of the entire sample collection procedure will result in greater variations than if multiple samples were collected at the same time. In addition, each collection set will represent a separate, although related, group of operating conditions and recycled media characteristics. After removing the final test sample from point 11, allow a larger sample to accumulate for the following cyclone efficiency and point 12 particle size distribution determination.

STEP 8 - Size Distribution and Cyclone Efficiency (Point 12). In order to understand the rationale and necessity of this procedure, a brief discussion of the process is required. As shown on Figure 1, used media exits the blast booth by either of two routes. The majority of the usable media falls to the floor, is continuously picked up by a pneumatic conveying system and delivered to the separation cyclone. Lighter material exits the top of the cyclone where it joins the second route of media removal, the booth ventilation system. The combined streams then run to a negative pressure baghouse where filters capture the spent media. Any usable media reaching the baghouse to either escaped the cyclone (point 12) or was picked up directly by the ventilation system.

If samples at point 12 were collected by removal of the connection hose or ducting, the cyclone would no longer discharge into the negative pressure of the baghouse. Consequently, the velocity of the air discharging into atmospheric pressure would become lower. Lower air velocities would result in less carry over of larger particles from the cyclone and would not represent normal operating conditions or usable media losses. In order to accurately determine cyclone separation efficiency under actual operating conditions, the following test procedure is proposed:

1. Collect a representative floor sample (Point 11) using the previously described method. Allow approximately 50 pounds to accumulate for each test sample.

2. Determine the size distribution by sieving the sample and measuring the weight of each fraction. Remix the sample and recheck the total weight.

3. Inspect and adjust the diverter valve for tight shut off when operating in the full screen bypass position as indicated on Figure 1.

4. Spot check the pounds of diverted media per minute that flow from the bypass during normal blasting operation. Multiple measurements will be required to determine an average and approximate range. Use a stopwatch to determine the time required to fill a convenient container. Determine media weight in container.

5. At the beginning of a scheduled break in blasting operations, secure the diverter valve in the bypass position. When media flow has ceased, empty the collection drum and reinstall.

6. Slowly pour the collected test sample into the floor recovery system at a rate (pounds of media per minute) slightly greater than that measured at the diverter as previously described (Item 4). Capture all the material in the collection drum.

7. The difference, by weight, in each size distribution range of the initially collected feed sample (point 11) and the sample just collected using the diverter valve has been lost to the dust collector. For example, the exact amount of usable media returned by the cyclone for recycle divided by the exact amount fed to the cyclone is known. This value multiplied by 100 is defined, for the purpose of this study, as "cyclone efficiency".

This procedure will be repeated for additional accuracy. A test performed at the maximum observed loading rate could yield greater losses if the cyclone is undersized or the fan is incorrectly specified. If the equipment is inherently inefficient or found to be load sensitive in normal operating ranges, further investigation may be warranted.

2.2 Walk-in Blast Booth at Hill AFB, Ogden, Utah

2.2.1 Background

Recycle equipment for this 15 feet by 30 feet walk-in blast booth was supplied by CABER, Inc. This site utilizes similar types of separation equipment as the NARF Pensacola walk-in booth, however, several system design differences exist. As shown in the schematic of the system (Figure 2), a cyclone, star valve, and vibrating screen separator are employed.

Unlike the NARF Pensacola walk-in booth, this system does not recover any appreciable amount of material on a continuous basis during the blasting operation. Rather, the floor is periodically swept clean into a small corner pit which feeds the recycle system. With this operation, the cyclone was designed to operate at higher media feed rates. The fan in this system is externally mounted between the cyclone and baghouse.

2.2.2 Sample Collection Procedure

The various samples to be collected (for each of the points indicated in this section) shall weigh not less than 2 pounds, and shall be collected no less than twice during test procedures. All collected samples shall be contained in ziplock bags, labeled, and stored pending later analytical procedures. As a minimum, samples will be subjected to particle size distribution and specific gravity determination.

A detailed explanation of the procedure to be employed follows.

STEP 1 - Cyclone Feed (Point 4). Start blasting operations with a thoroughly cleaned booth floor. Alert the operators not to sweep the floor after completion of blasting. After blasting, sweep the floor thoroughly clean into an area near the cyclone feed pit. Mix the collected material. Obtain a sample for total metals analysis. Collect larger samples of approximately 50 pounds each for later testing. Sieve the entire 50 pound samples determining size distribution by weight. Remix the samples and recheck the total weights.

STEP 2 - Cyclone Rejected Dust (Point 5). Loosen the interconnecting hose between the dust collector and baghouse. Run cyclone blower pulling the hose back to determine the pressure situation. Shut off blower. Fashion a collection vacuum cleaner bag the at cracked hose outlet or internal duct. Run blower and vibrating screen. Sweep some remaining floor material into the recycle system, point 4 (not the Step 1 collected samples) while collecting sample. Sample will be analyzed for total and leachable metals when combined with the sample collected at point 8. Repeat as required, sweeping more floor material into feed. This sample will not be used for particle size determination.

STEP 3 - Vibrating Screen Rejects (Points 7 and 8). During an extended break, shut off the vibrating screen and cyclone fan. Disconnect the interconnecting hose between test points 7 and 8 and install a cardboard diverter and collection drum under point 8 (screen dust rejects). Point 7 (screen oversize debris) samples will be collected in the drum normally used for collecting cyclone rejects.

STEP 4 - Usable Media (Point 10). Investigate the discharge of the magnetic separator to determine if a diverter can be installed. If so, install a collection drum to contain sample. Clean out separator. System is prepared to collect sample.

However, if installation of a diverter at point 10 is difficult, the following procedure will be implemented. Disconnect the usable media delivery hose from the vibrating screen, point 9, and fashion a cardboard diverter and collection drum. Collect a sample at that point. Pour a sample collected at point 9, of known characteristics, into the magnetic separator and obtain the magnetic particles collected at point 9A. The difference (by weight) between the sample introduced at point 9 and obtained at 9A will define the separator, point 10.

STEP 5. Just prior to introduction of the first 50 pound floor sample (Point 4), run some excess material through the system and observe the collection apparatus just installed. Empty all containers and reinstall. Empty the entire contents of the prepared sample into the cyclone feed pit. Samples will be automatically collected at points 7 (screen oversize rejects), 8 (screen dust rejects), and 10 (usable media).

STEP 6. Collect and separately determine the size distribution by weight of sample points 7, 8 and 10. The difference between the additions of each of the collected size distributions and the respective distribution weights taken from the initial, preweighed, feed sample is the amount (by weight) of each size distribution lost to the dust collector. In this manner, the separation efficiency of the cyclone is determined. Repeat test to verify accuracy.

In order to characterize the cyclone, an additional test using material with a larger percentage of usable media is recommended. Tests using normal feed with different settings of the cyclone damper could provide valuable information. All these tests could be done during the same test period using multiple 50 pound (point 4) prepared feed samples.

2.3 F-4 Aircraft Blast Booth at Hill AFB, Ogden, Utah

2.3.1 Background

The recycle equipment services a large booth capable of holding a complete F-4 aircraft for PMB. Although the blast equipment design can support up to five blasters simultaneously, no more than three are normally used, due in part to high dust levels in the work area. Figure 3 is a schematic of the system. The floor is designed to automatically pickup and pneumatically convey used media through a duct system which feeds a separation screen. Usable media from the screening system is recycled back to the blast feed vessels via two mechanical conveyors. Large amounts of new media are regularly introduced into the system offering strong economic incentives to characterize the efficiency of the recycle system.

2.3.2 Sample Collection Procedure

The various samples to be collected (for each of the points indicated in this section) shall weigh not less than 2 pounds and shall be collected no less than twice during test procedures. All collected samples shall be contained in ziplock bags, labeled, and stored pending later analytical procedures. As a minimum, samples will be subjected to particle size distribution and specific gravity determination.

A detailed explanation of the procedure to be employed follows. In order to collect samples of reject dust from both dust collector systems (points 2 and 19), start testing with dumped (cleaned) systems.

STEP 1 - <u>Floor Pickup</u> (Point 1). Cover an area near actual blasting with a flat sheet of cardboard or other suitable material. Instruct the operators not to aim the blast nozzles directly at the collection area. If this proves ineffective, plugging floor collection funnels in selected areas is an alternate means of collection. This sample will be analyzed for total metals content.

STEP 2 - Usable Media Return (Point 3). Usable media is fed to the blast vessels from the screen system via two conveyors. Remove the small access covers from the conveyors. Collect a 1 pound sample from each conveyor discharge and place both samples into the same zip-lock bag. The sample will be analyzed for total metals content.

STEP 3 - Baghouse Dust (Point 2). Collect a sample of the baghouse dust generated during this period of operation. The sample will be subjected to a particle size determination. Save 1 pound for mixing with a 1 pound sample of point 19 for leachable metals analysis.

STEP 4 - Recirculation System Dust (Point 19). Collect a sample of the dust generated during this period of operation. Save 1 pound for mixing with a 1 pound sample collected at point 2 for leachable metals analysis.

STEP 5 - Oversize Screen Rejects (Point 2A). Collect a sample at point 2A.

2.4 Additional Process Measurements and Information

The following additional measurements and information will be acquired, where possible, and utilized for equipment evaluation.

1. Blower and motor information including actual motor amperage, differential pressure and impellor type/size.

2. Type of paint being blasted.

3. Description of media being used and amount consumed.

4. Question operators as to the current operating performance of the system, current/required maintenance and any suggested improvements.

5. Physical dimensions of baghouse, filter type/area.

6. Differential pressure, air flow rate and configuration of initial separation device (cyclone or ducting).

2.5 Maintenance/Reliability Information

The following information shall be acquired and form part of the equipment evaluation:

1. Vacuum Fan. Room and ease of motor/impellor replacement. Existence and replacement of protection screens at inlet. Bearing condition and ease of service. Existence of grease fittings. Starter condition. Existence and service of belts, shaft seals, etc.

2. Blast Air System. Compressor type and load response. Oil pressure, color, temperature, etc. Motor information and actual amperage. Blast nozzle wear. Handling ease.

3. Fines Separation Ducting or Cyclone. Make detailed sketch. Inspect/locate access doors. Abrasion assessment. Depth of engineering design. Effectiveness.

4. Screening System. Reliability appraisal of mechanism. Waste removal ease. Parts, motor and screen replacement. Plugging characteristics.

5. Floor Media Return System. Observe any mechanical build up. Reliability and performance. Maintenance aspects and accessibility. Quality of components.

6. Recycle Return Conveyors. Observe bearing/slider wear, stretch and alignment. Access reliability.

7. Baghouse. Ease of bag (or filter) replacement and system cleaning. If automated, scrutinize pulse/cleaning system.

8. Instrumentation and Control Systems. Reliability and quality assessment.

Additional information may be obtained pending further observation of equipment, working conditions and operating parameters.

2.6 Data Acquisition and Reporting

1. Raw Data Sheets. The proposed raw data sheet is included as Appendix A. Exact times of data collection are recorded with each value for process continuity. Space is provided for additional parameters. The log section affords the record of events which may impact the results.

2. Specific Data Requirements. Desired specific data requirements for each sample point have been tabulated and are included in Appendix B.

3. Data Reporting. Final results will be reported, in part, using a similar tabulation method. Actual real time operating rates of the separation equipment will also be reported. Capacity-efficiency interdependency will be explored.

3.0 LABORATORY ANALYSES

Many of the samples collected during the on-site testing at Hill AFB and NARF Pensacola will be subjected to various laboratory analyses. The analyses include determinations of specific gravity and analyses to determine the concentration of specified metals.

3.1 Analysis of Media and Dust for Metal and Silica Content

Selected samples from the three PMB sites will be analyzed for total metal content (cadmium, chromium, lead, nickel, iron, zinc, titanium, aluminum, barium), according to Occupational Safety and Health (OSHA) Personnel Exposure Limits (PEL) testing protocols. The determinations will be made using inductively coupled plasma analysis in accordance with the National Institute of Occupational Safety and Health) (NIOSH) Method 7300. The samples will also be subjected to a colorimetric determination for silica contamination.

3.2 Analysis of Dust for Leachable Metal Content

Up to three samples of dust will be segregated into three size ranges; >100 mesh, 100 to 200 mesh, and <200 mesh. Each size range will be analyzed for leachable (EP toxicity protocol) metals listed in 3.2. The determinations will be made using inductively coupled plasma analysis in accordance with NIOSH Method 7300.

3.3 Determination for Specific Gravity

The specific gravity of selected samples from the three PMB sites will be determined.

4.0 GOVERNMENT SUPPORT REQUIRED

It is anticipated that close coordination with officials and managers of the host activities will be mandatory to reduce and/or eliminate any significant disruptions of their production schedules. Assistance will be required to allow the test team daily access to the base and the test site.

4.1 Support Required at the Walk-in Booth at NARF Pensacola

While inside the booth, selected grates will be lifted, the small funnel outlet holes temporarily covered with wide duct tape and the grates replaced. This procedure should require less than one hour in the booth.

Small samples will be taken from the obstructed areas during breaks in operation without interfering with the production schedule.

Between shifts or during an extended break, large samples will be obtained from the obstructed areas. This procedure should require approximately one hour.

The use of the fan and vibrating screen on-off power switches will be required during break periods.

A ladder will be required to access recycling equipment.

Access to a 110 volt (V) electrical outlet will be required.

4.2 Support Required at the Walk-in Booth at Hill AFB

Testing will commence with a clean (swept) floor and operators will be requested no to sweep the floor after blasting.

Test personnel will require approximately one hour break in blasting operations to collect floor samples.

The use of fan and vibrating screen on-off power switches will be required during break periods.

Access to a 110 V electrical outlet will be required.

4.3 Support Required at the F-4 Aircraft Blast Booth at Hill AFB

Two flat sheets of cardboard or plywood will be placed on the floor of the booth in order to collect media samples. Test personnel will require access to the booth for test setup and later sample collection, however, it is anticipated that these activities will be accomplished during normally scheduled breaks in blasting operations. Operators will be requested not to point the blast nozzles directly at the collection areas.

A ladder will be required to access recycling equipment.

Access to a 110 V electrical outlet will be required.

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